

# A joint project of the University of Brasilia and the International Centre for Theoretical Physics on GNSS applications

**Claudia Papparini, Renato A. Borges, Xurxo O. Villamide and Sandro Radicella**

Emails: [papparini@ictp.it](mailto:papparini@ictp.it), [raborges@ene.unb.br](mailto:raborges@ene.unb.br), [xotero\\_v@ictp.it](mailto:xotero_v@ictp.it) [rsandro@ictp.it](mailto:rsandro@ictp.it)

ICG Experts Meeting:  
Global Navigation Satellite Systems Service

14 - 18 December 2015, Vienna, Austria

# GLONASS in Brazil

## Timeline Overview:

- **2006** - Brazilian and Russian governments signed an agreement to install GLONASS reference and monitoring stations in Brazilian territory;
- **2012** - Brazilian Space Agency elected University of Brasília to receive the first station;
- **2013** - GLONASS Differential Correction Station starts operation;
- **2014** - GLONASS Quantum Optical Station with OWS starts operation.



# One Way Station (OWS) and LRS

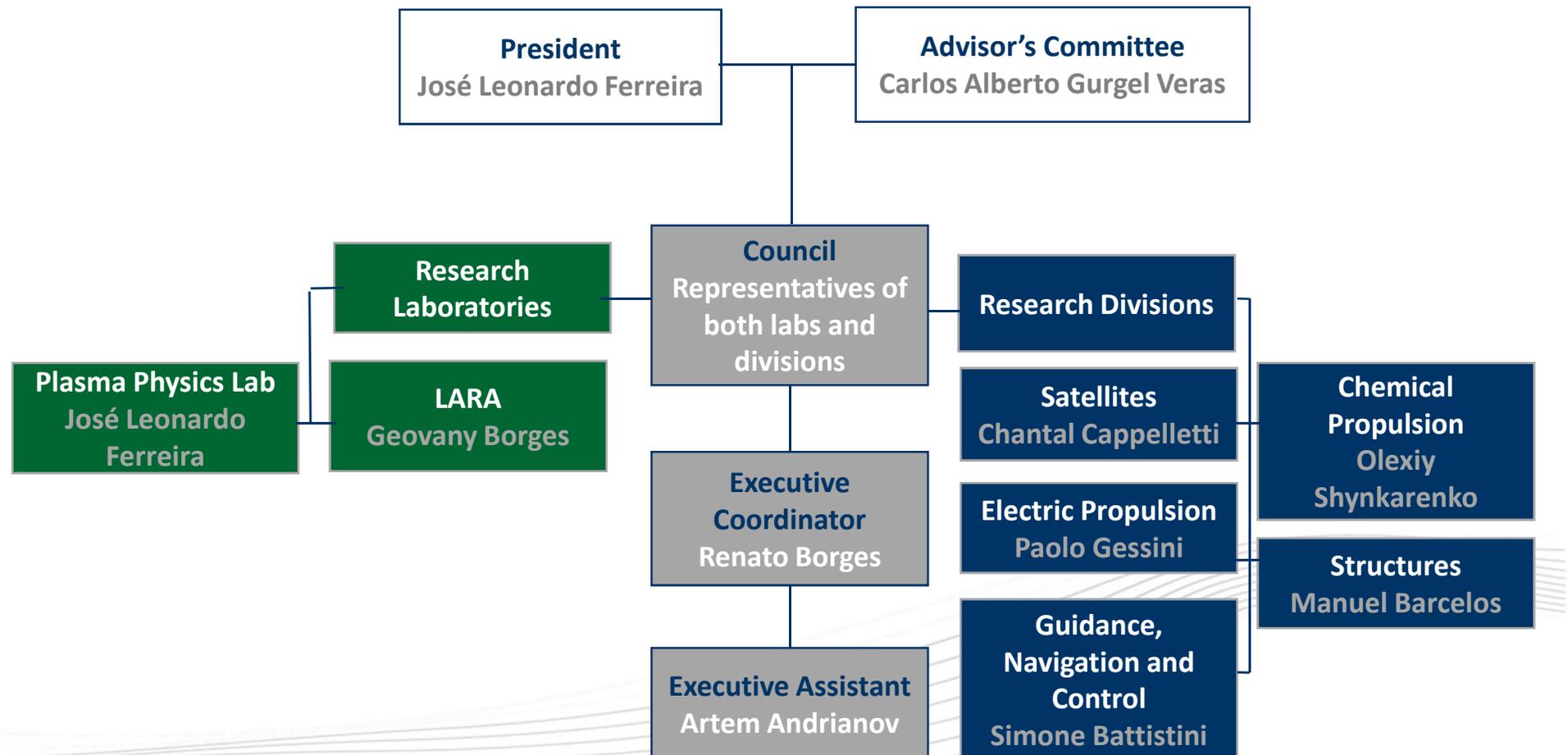
## OWS and LRS:

- L1 and L2 GNSS receiver MS-GLONASS IBPA.464346.003 (BRAJ station);
- IRLS Site Code BRAL, Station #7407, DOMES #48081S001, 15.7731 S, 132.1347 W;





## Aerospace Administrative Structure



# Cooperation Between UnB and ICTP

## Timeline Overview:

- **May 18<sup>th</sup> 2015** – ICTP and UnB representatives first talk during the Workshop on Applications of GNSS at Krasnoyarsk, Russia;
- **Sept. 15<sup>th</sup> 2015** – Official Letter in support of the cooperation enters into force;
- **Sept. 22<sup>nd</sup> 2015** – FTP server for data transfer set up;
- **Sept. 25<sup>th</sup> 2015** – Measurement data transfer protocol signed;
- **Oct. 1<sup>st</sup> 2015** – Regular data transfer started;
- **Dec. 2015** – MoU formalizes the scientific research cooperation between the UNB and the ICTP in the field of PPP in the region of Brasilia (in progress).

APPROVED

Director General  
JC-APRC-SPS

UNIVERSIDADE DE BRASÍLIA

ICTP

MEMORANDUM OF UNDERSTANDING  
between  
Fundação Universidade de Brasília (FUB),  
Campus Universitário Darcy Ribeiro, 70910-900, Assa Norte, Brasília DF,  
Brazil,  
and  
International Center of Theoretical Physics (ICTP),  
Strada Costiera 11, 34014 Trieste, Italy

PROTOCOL

For the University  
FUB President  
For the Laboratory for Application and  
Innovation in Aerospace Science,  
Head of Division  
Borges RA

For JC-APRC-SPS  
Head of department ADS  
Bukharinov E.V.

For JC-APRC-SPS  
Director General  
Yu.A. Izrael

Official Letter

In support of cooperation between the University of Brasilia and the Abdus Salam International Center for Theoretical Physics in the context of Contract TM-2011-Instalation MS-GLOASS-*satlon-TM-BR* in the Territory of the Federative Republic of Brazil.

Under the terms of the Additional Agreement N° 4 to the Contract (11/2011) installation MS-GLOASS-*satlon-TM-BR* in the Territory of the Federative Republic of Brazil between the University of Brasilia and the International Center for Theoretical Physics (ICTP), the Parties have agreed to allow the University of Brasilia for carrying out own research works with the right of the open publication of results.

Due to the international character of the research work conducted at the University of Brasilia, and in accordance with the Additional Agreement N° 4 mentioned above, we officially declare our support for the cooperation between the University of Brasilia (FUB), Brasilia, Brazil, and the Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italy, in the context of the implementation of the contract (11/2011) installation MS-GLOASS-*satlon-TM-BR* in the Territory of the Federative Republic of Brazil.

The purpose of the cooperation is to allow the University of Brasilia to carry out own research works with the right of the open publication of results.

In this framework, we officially state that the measuring information from the GLOASS receiver (RTK) obtained can be used by the University of Brasilia for carrying out the research work described in Annex 1. The responsibility for the cooperation project are Dr. Renato A. Borges, one of the coordinators of the Laboratory for Application and Innovation in Aerospace Science, and Dr. Nikolai A. Bukharinov, Professor and Head of the Department of Navigation and Positioning at the Laboratory for Application and Innovation in Aerospace Science at ICTP.

This Official Letter enters into force from the date of its signing by both Parties.

Signed on **04/09/2015** in Moscow, the Russian Federation and **05/02/2015** in Brasilia, the Federative Republic of Brazil.

For JC-APRC-SPS  
Director General  
Yu.A. Izrael

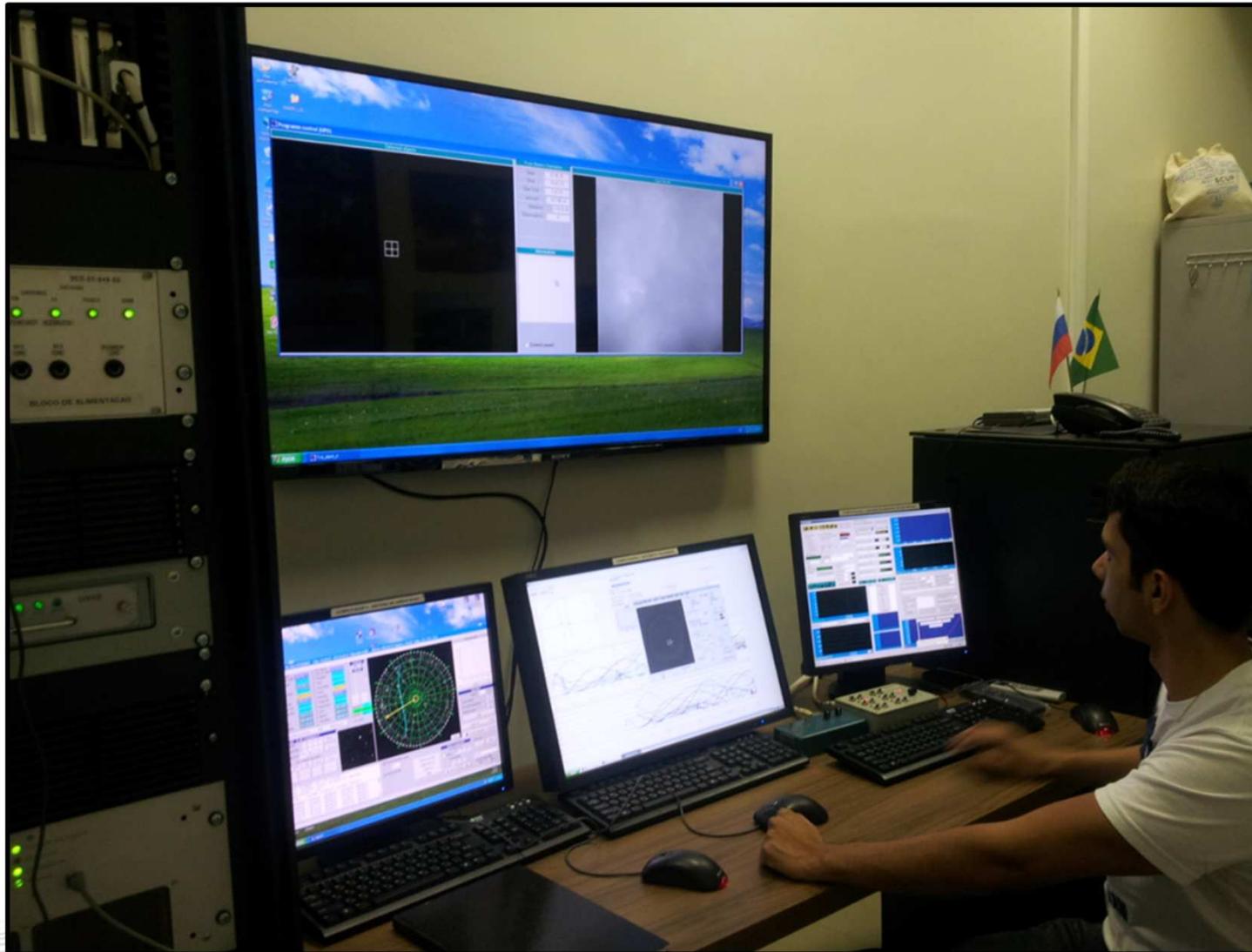
For the University  
FUB President  
Dr. Renato A. Borges

For JC-APRC-SPS  
Head of department ADS  
Bukharinov E.V.

For the UnB Laboratory for Application and Innovation in Aerospace Science,  
Head of Division  
Borges RA

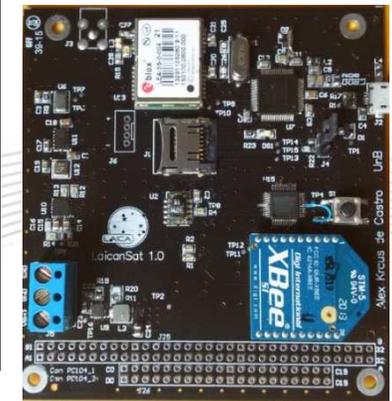
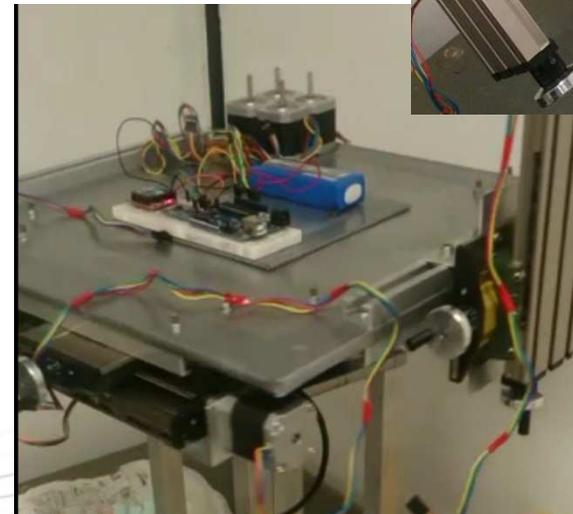
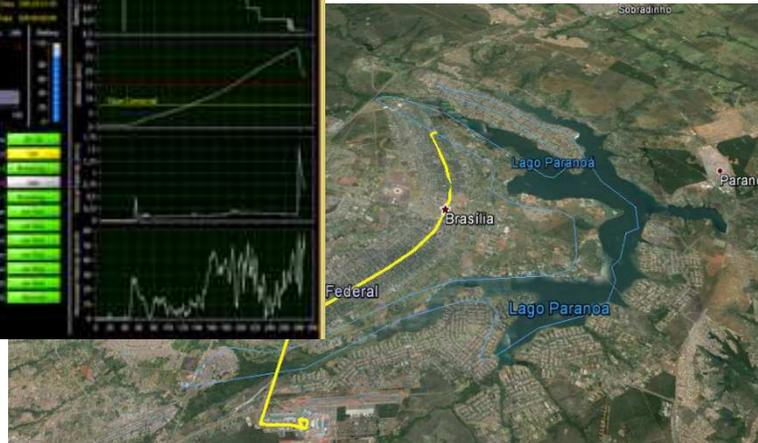
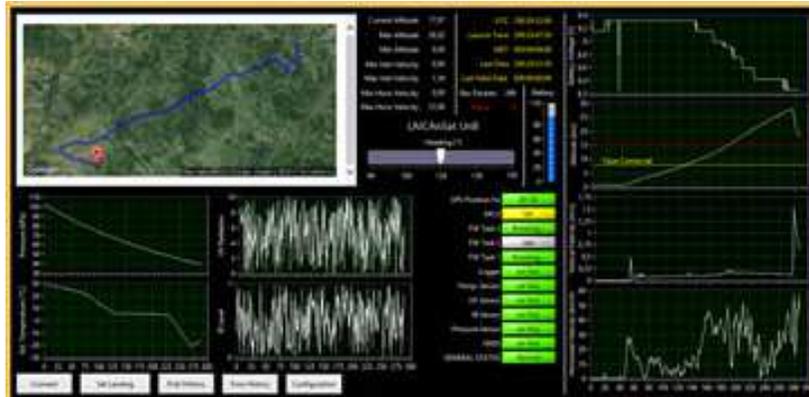


## Laser operation and data transfer server room



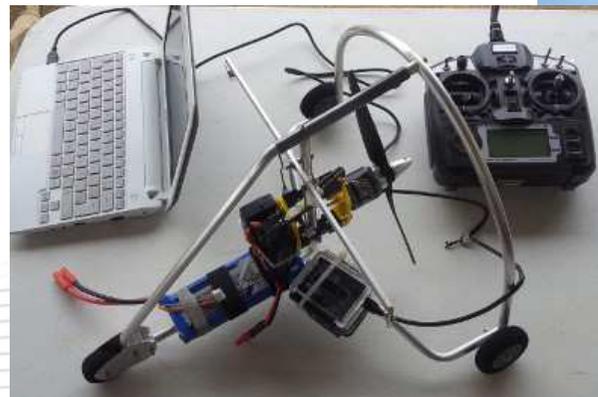
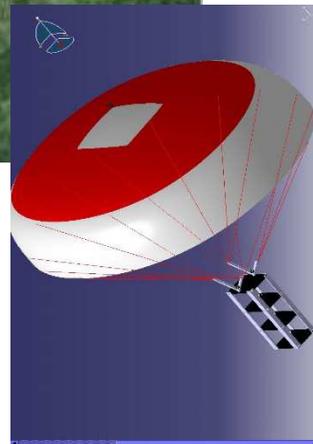
# Associated Research and Development

Possible applications and test facilities:



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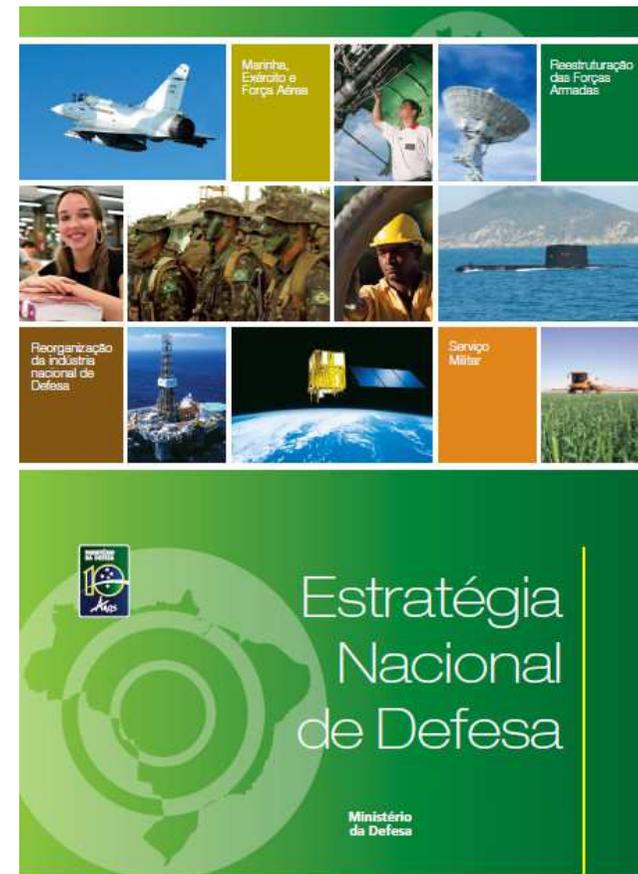
# Associated Research and Development

## Topics for investigations :

- uBlox M8 GNSS single frequency module:
  - Ionospheric correction models;
  - Impact point prediction;
  - Attitude determination and control.
- MS-GLONASS IBPA.464346.003 dual frequency receiver:
  - Precise Point Positioning (PPP).

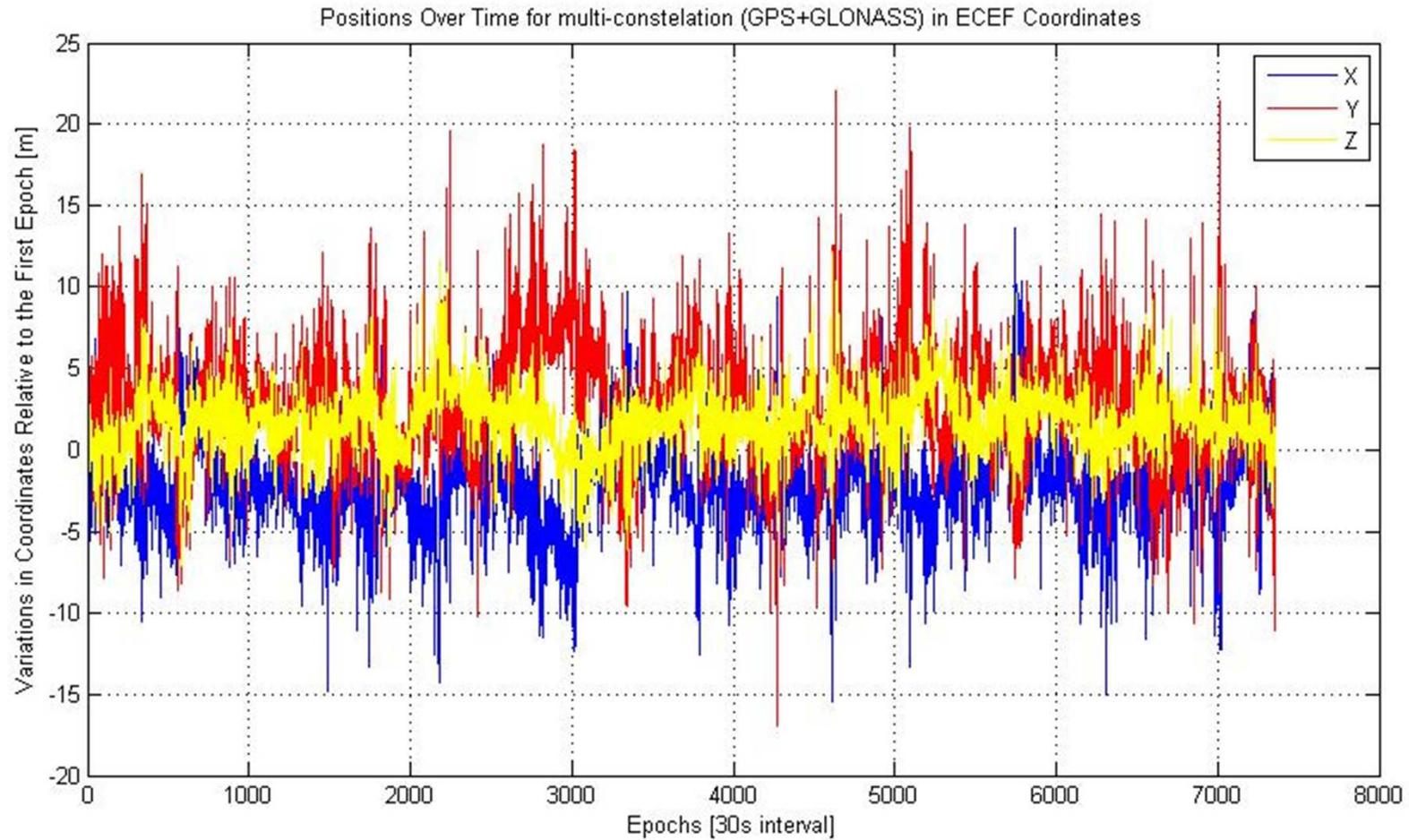
## Brazilian national defense strategy :

- Project aligned with the interests of the Defense Ministry;
- Improve and develop national capability in the field of geolocation and positioning.



# Associated Research and Development

Preliminary results - Point positioning using uBlox M8 module.



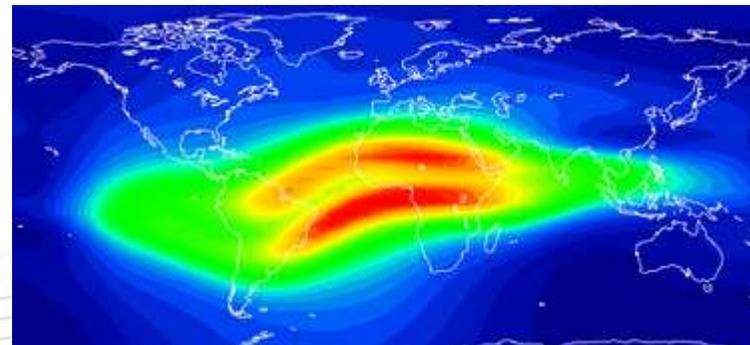
## PPP Project - Objective

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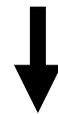
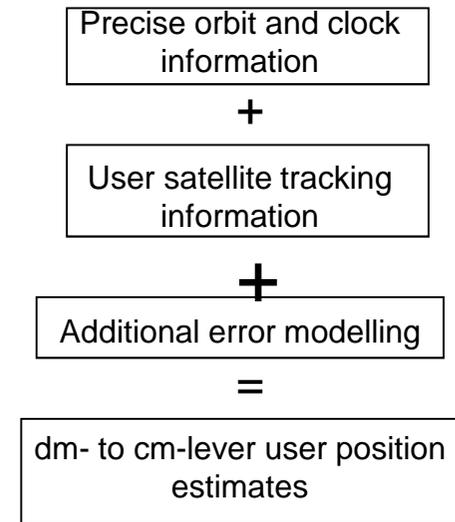
The overall objective of the proposed research on Precise Point Positioning (PPP) is to assess the **impact of multi-constellations** instead of stand-alone (GPS or GLONASS) PPP solution around Brasilia. Data are extracted from the GNSS receiver of the One-Way Station (OWS) MS GLONAS, «Sazhen-TM-BIS» installed at University of Brasilia.

This region is strongly affected by the Ionospheric Equatorial Anomaly (IEA) that implies **high variability in the ionosphere**.



# Precise Point Positioning – PPP – using MCDF Measurements

- PPP is a undifferenced positioning technique that combines dual-frequency code and phase observations.
- It uses precise ephemeris, accurate satellites clock corrections and physical models to provide sub-meter, centimeter and millimeter accuracy, depending on the application and receiver dynamics (static , kinematic solutions).
- Accuracy and convergence time are compared for GPS-only and GPS/GLONASS

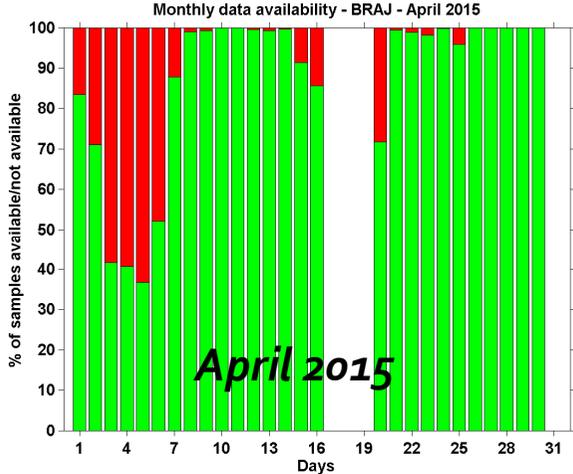
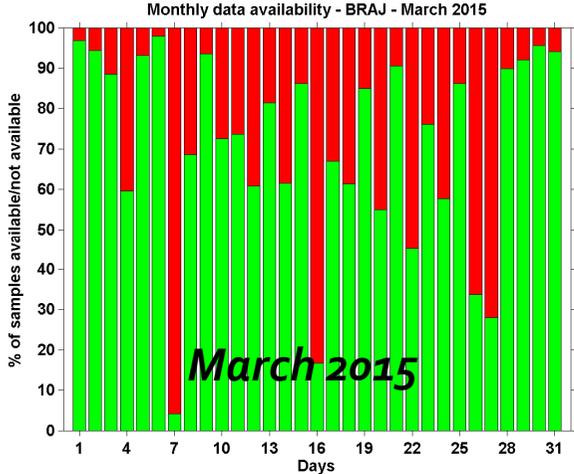


## Months analysed

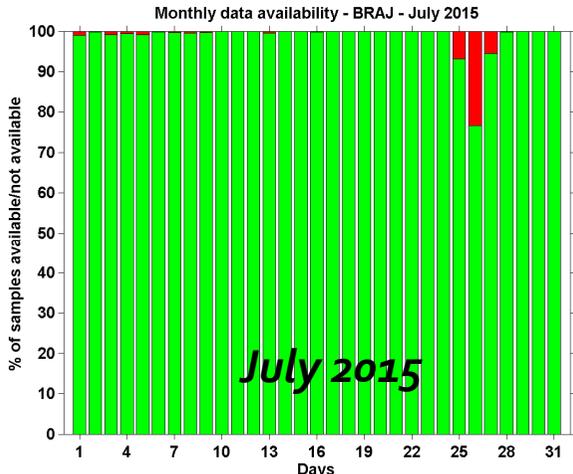
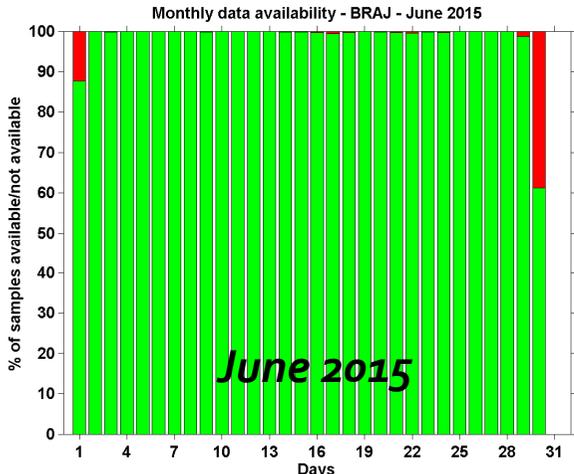
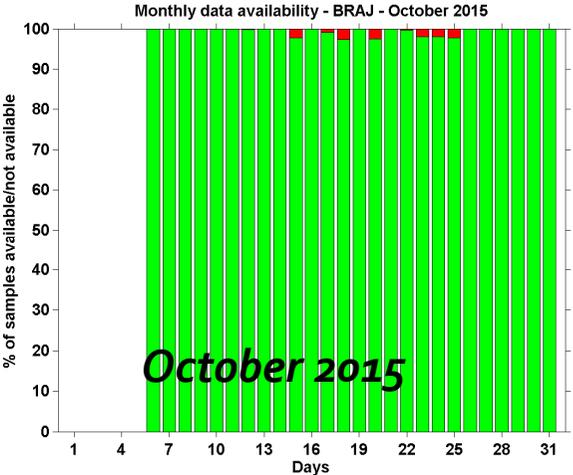
March, April, October 2015 (equinoctial period)

June, July 2015 (solstitial period)

# BRAJ Monthly Availability



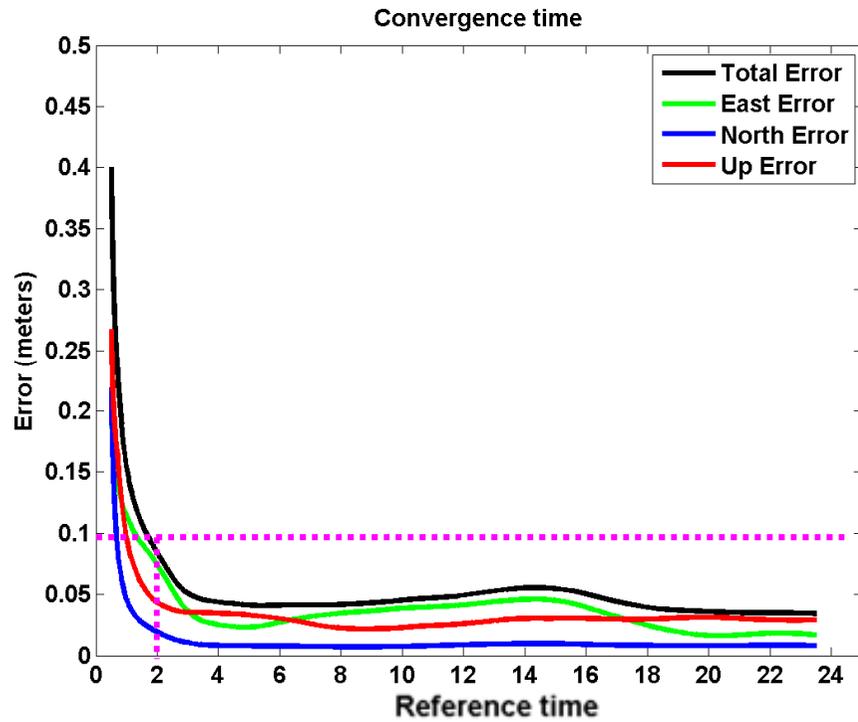
Days with data samples < 85% not considered for the analysis



Monthly values		North Error (m)	East Error (m)	Up Error (m)
March 2015	G	0.007 ± 0.183	0.024 ± 0.115	0.127 ± 0.402
	M	0.026 ± 0.113	0.027 ± 0.076	0.081 ± 0.252
April 2015	G	0.035 ± 0.115	0.034 ± 0.095	0.109 ± 0.355
	M	0.040 ± 0.100	0.021 ± 0.067	0.056 ± 0.225
June 2015	G	0.037 ± 0.100	0.010 ± 0.037	0.009 ± 0.170
	M	0.036 ± 0.096	0.018 ± 0.028	0.021 ± 0.109
July 2015	G	0.034 ± 0.050	0.016 ± 0.073	0.025 ± 0.076
	M	0.032 ± 0.045	0.019 ± 0.053	0.034 ± 0.063
October 2015	G	0.094 ± 0.235	0.026 ± 0.089	-0.095 ± 0.494
	M	0.081 ± 0.188	0.034 ± 0.083	-0.055 ± 0.364

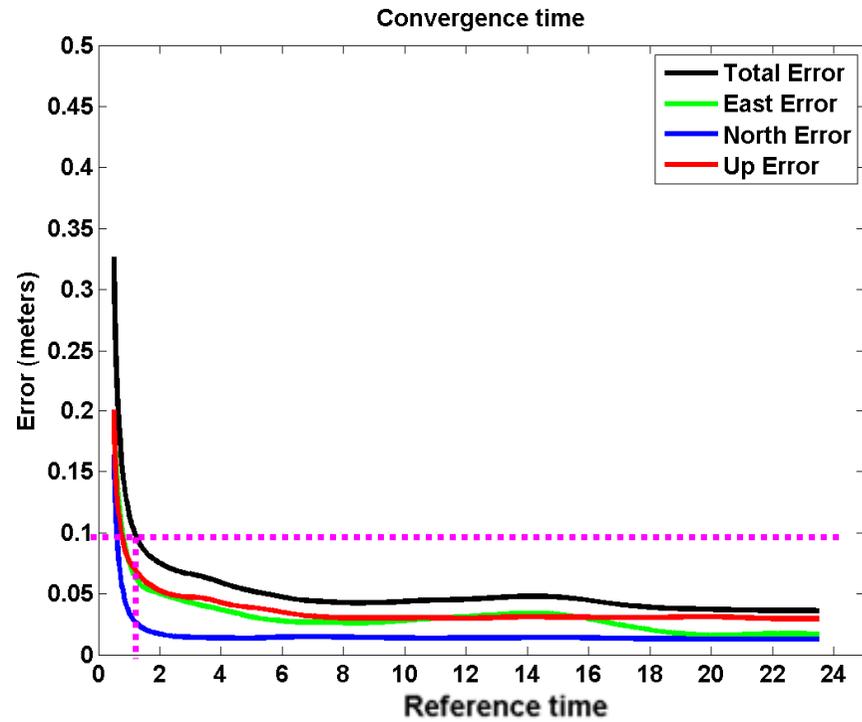
G = GPS, M = mixed (GPS + GLONASS)

# Convergence time comparison



*July 2015*

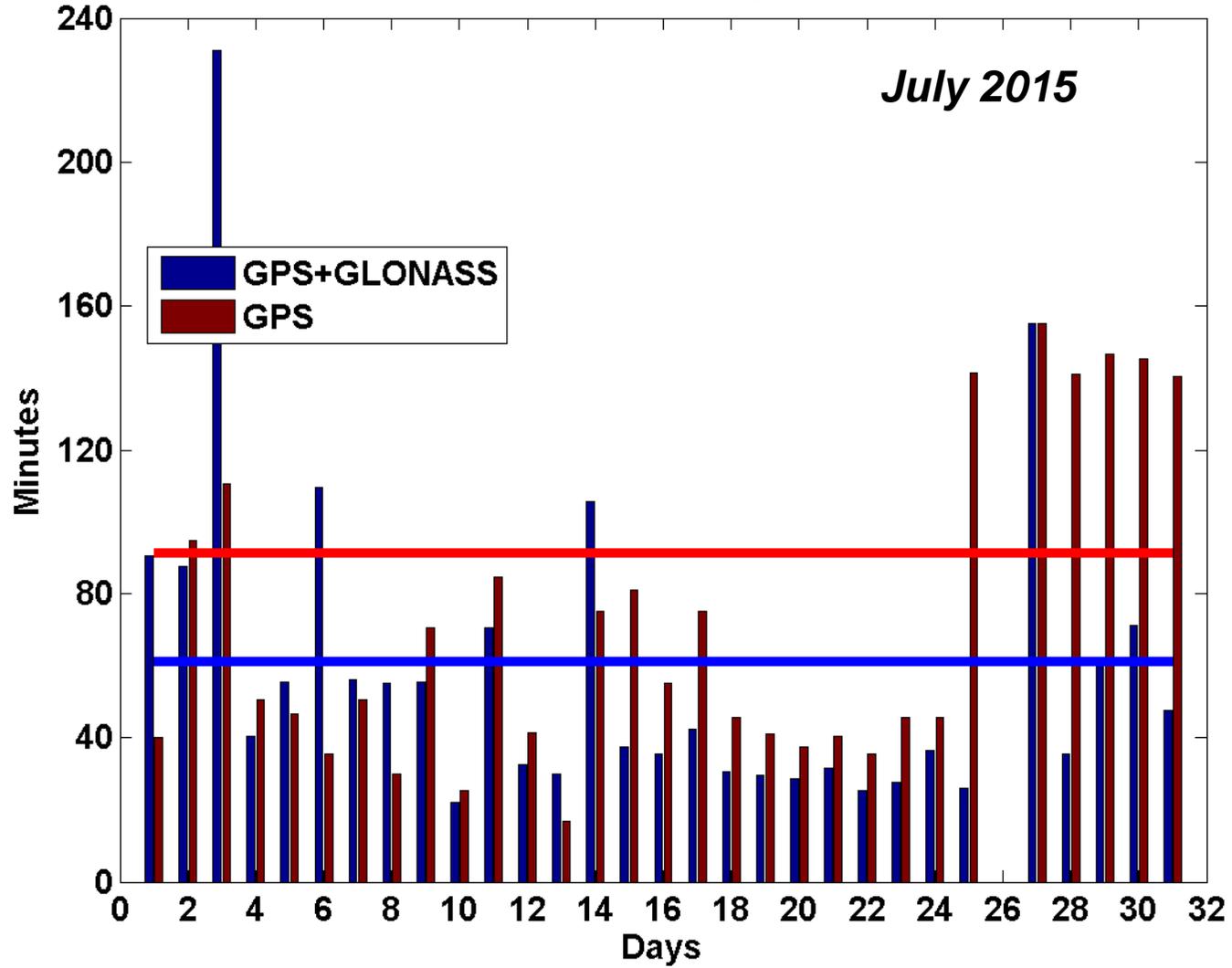
*GPS*

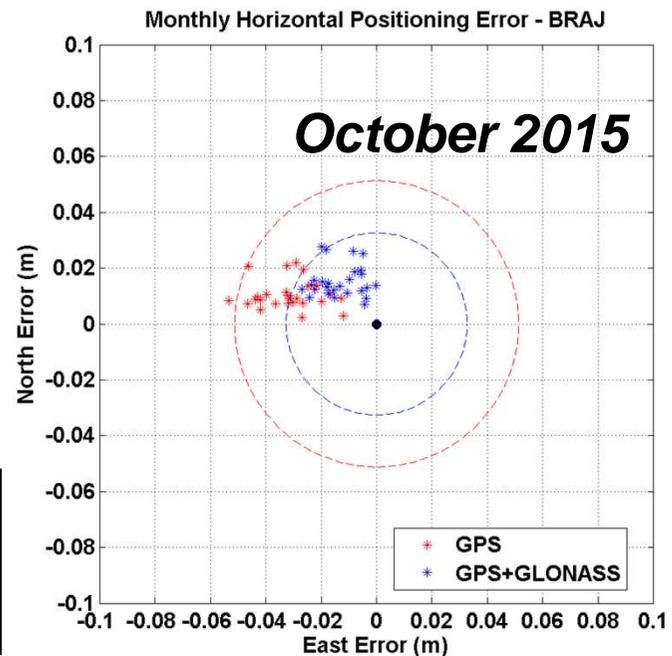
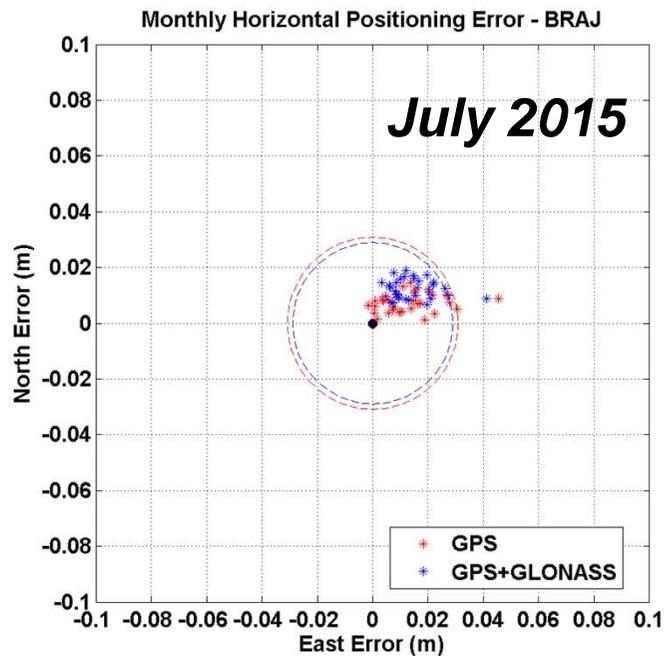
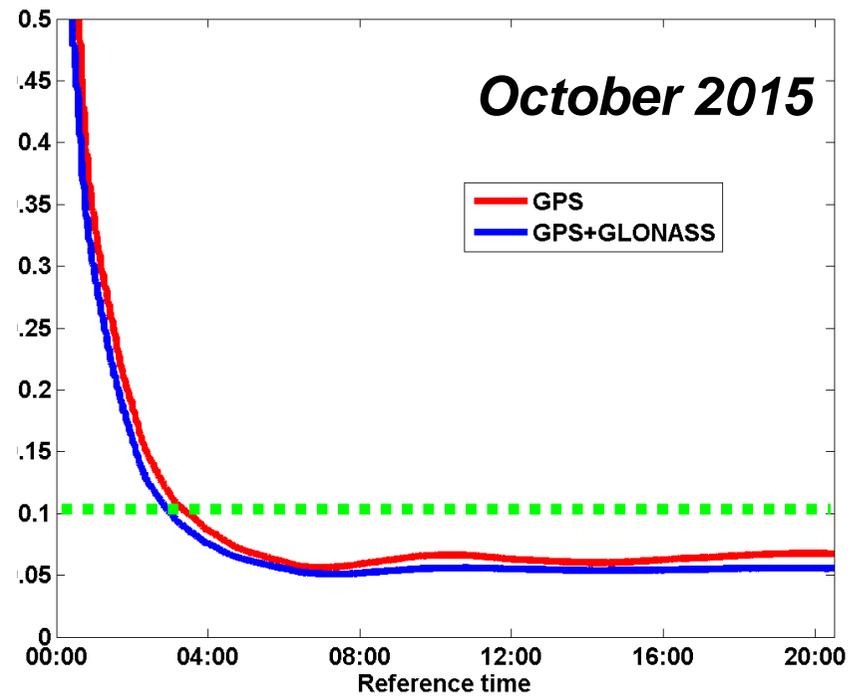
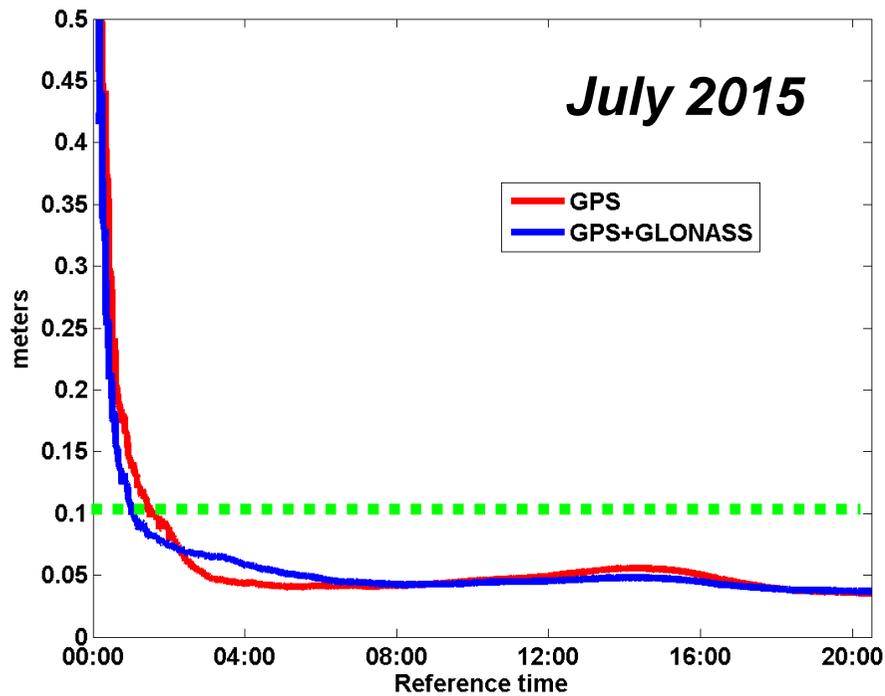


*July 2015*

*GPS/GLONASS*

Time necessary to converge < 0.1 meters

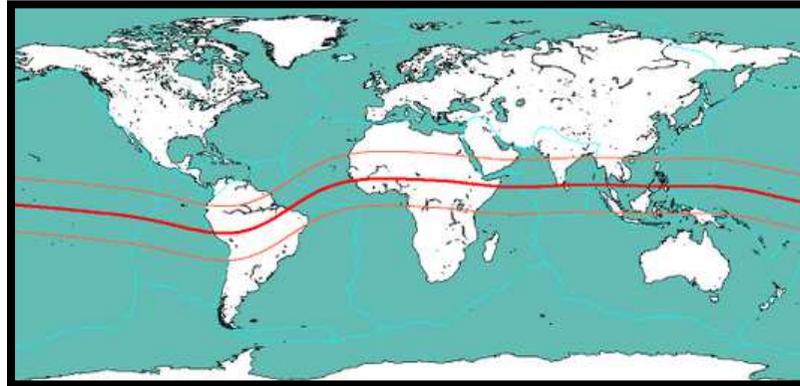




**Position Accuracy**

# Ionosphere Features

The IEA is characterized by two crests of electron density at  $\pm 20^\circ$  North and South of the geomagnetic equator and a minimum at this Equator.



- **IEA** presents strong diurnal, day-to-day and seasonal variations and intense irregularities after sunset. It is influenced by solar and geomagnetic activity.
- **IEA development** maximizes during equinoxes (March, April and September, October) and it is lower during solstice months.
- Different **parameters** can be used to study Ionosphere variability: Total Electron Content (TEC), Rate of change of TEC (ROT), Rate of change of TEC Index (ROTI).

$$STEC = a \frac{f_1^2 f_2^2}{f_1^2 - f_2^2} (L_1 - L_2)$$

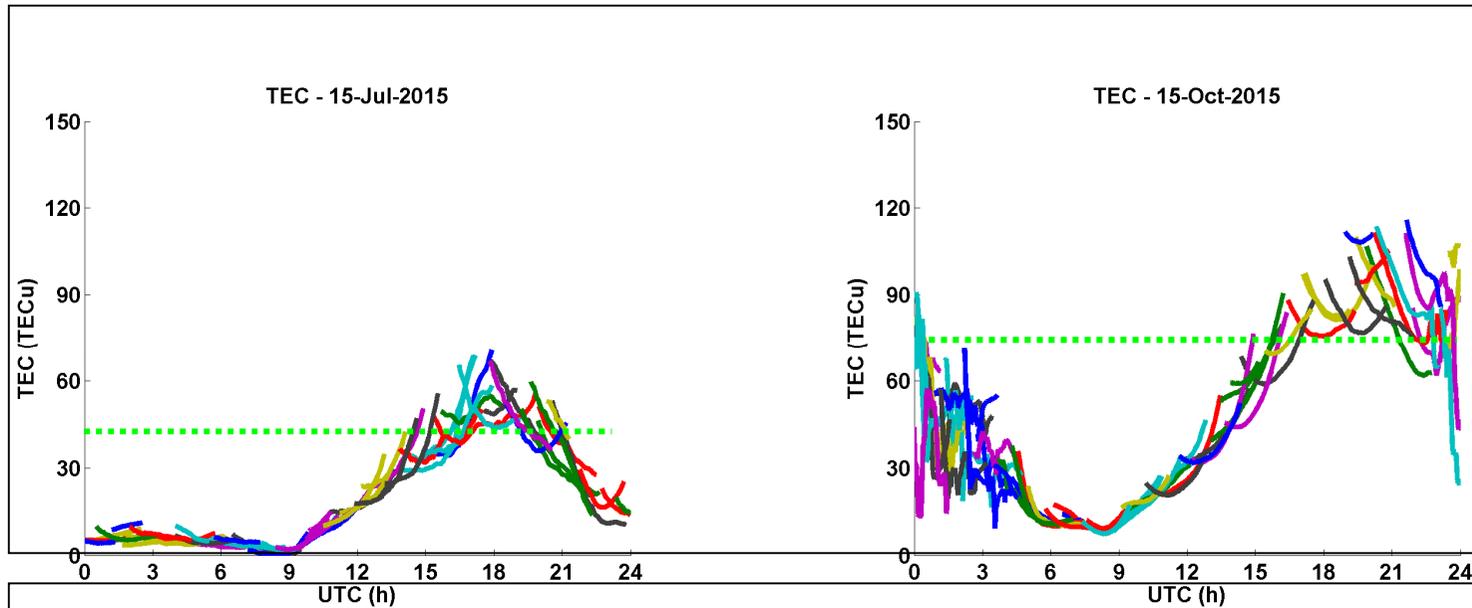
$$ROT = \frac{STEC_{k+1} - STEC_k}{time_{k+1} - time_k}$$

# BRAJ Station: Comparison solstitial (July) / equinoctial (October) period

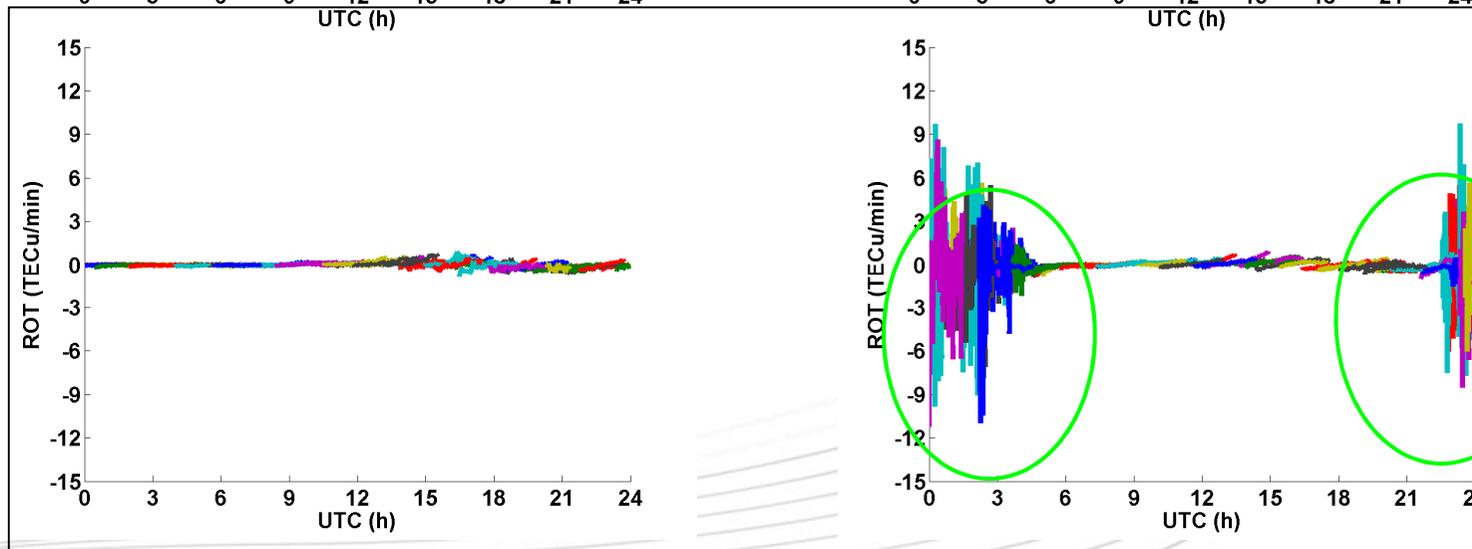
15 July 2015

15 October 2015

TEC

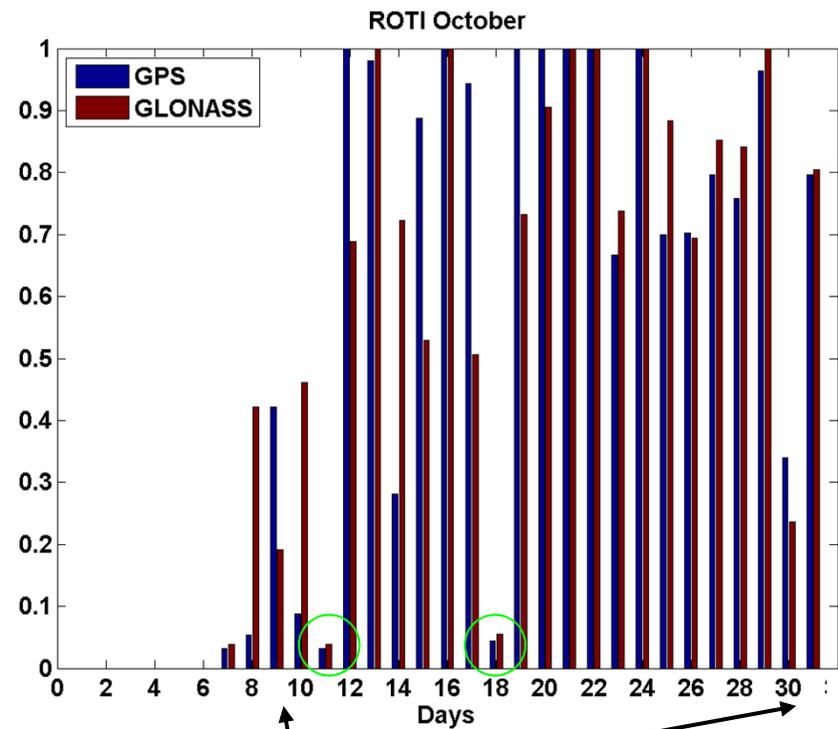
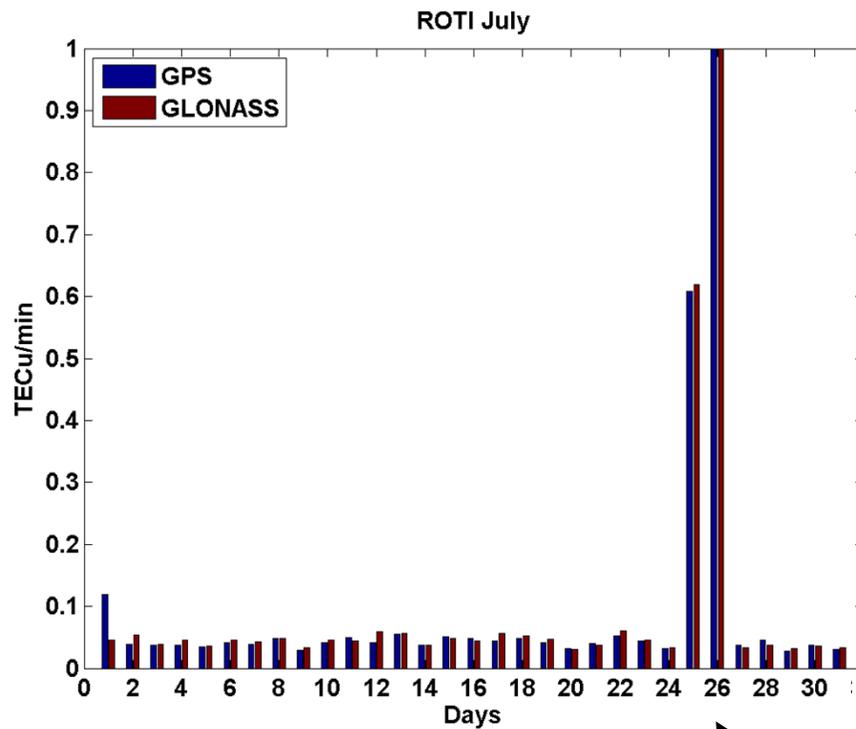


ROT



# Post Sunset Monthly ROTI

$$\text{ROTI} = \sqrt{\langle \text{ROT}^2 \rangle - \langle \text{ROT} \rangle^2}$$



Presence of Irregularities

## Results preliminary considerations (PPP)

- PPP results indicate an improvement in accuracy and convergence time when integrating GLONASS observations.
- PPP convergence results are degraded due to the post sunset ionospheric activity.
- Investigation within the PPP Project is going to continue in the region of Brasilia, Brazil (future installations at Northeast and South).

## Future perspectives include:

- Study and evaluation of ionospheric models for single frequency GNSS receivers;
- Practical applications on HASP (LAICAnSat);
- Onboard attitude determination;
- Impact point prediction;

Thank You For Your Attention!

Acknowledgements:



JC "RPC" "PSI"



ROSCOSMOS



UnB/DPP

