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

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ICG Experts Meeting:
Global Navigation Satellite Systems Service

14 - 18 December 2015, Vienna, Austria

GLONASS in Brazil

Timeline Overview:

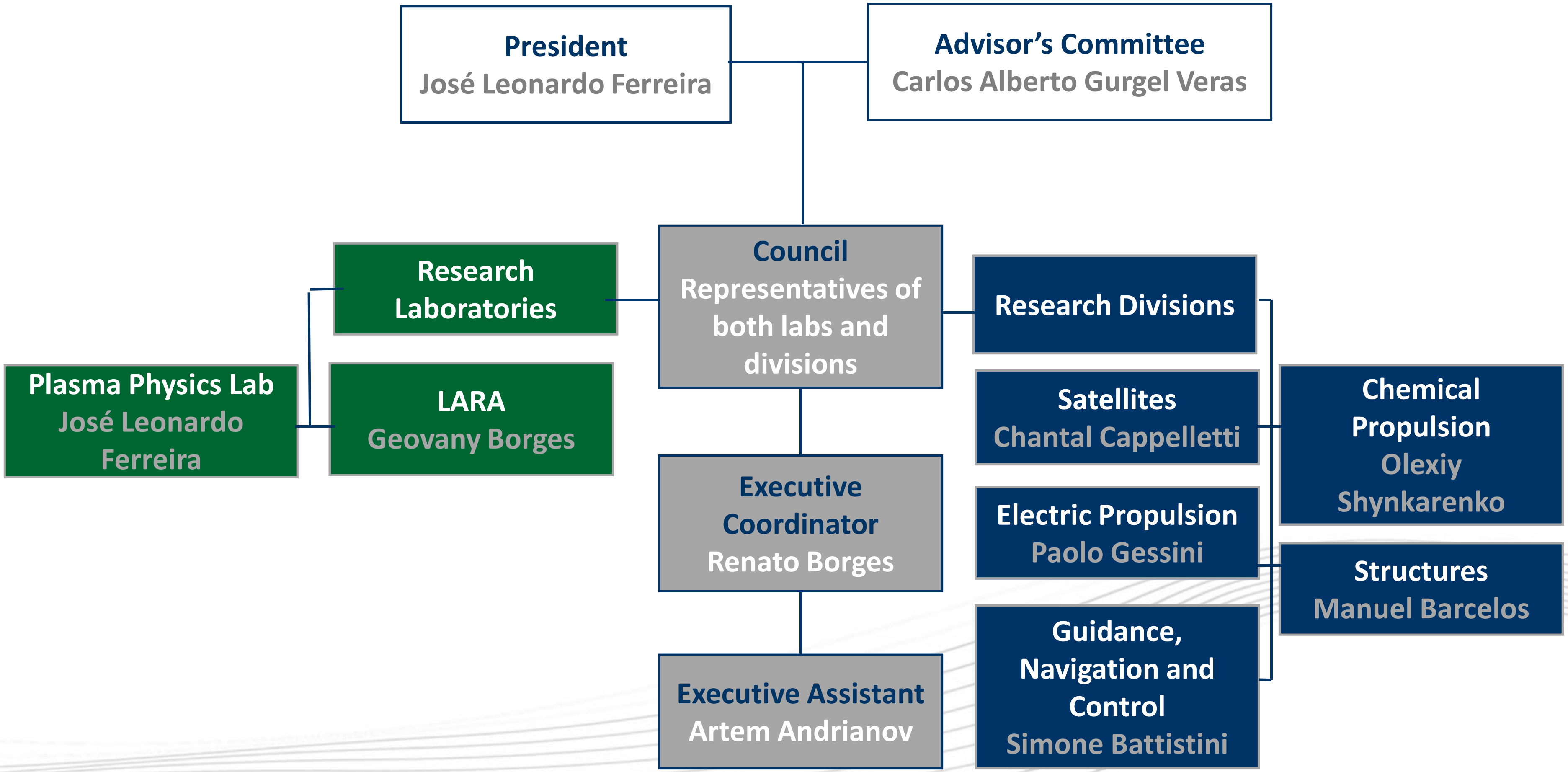
•**<u>2006</u> -** Brazilian and Russian governments signed an agreement to install GLONASS reference and monitoring stations in Brazilian territory;
•**<u>2012</u> -** Brazilian Space Agency elected University of Brasília to receive the first station;
•**<u>2013</u> -** GLONASS Differential Correction Station starts operation;
•**<u>2014</u>** - 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;

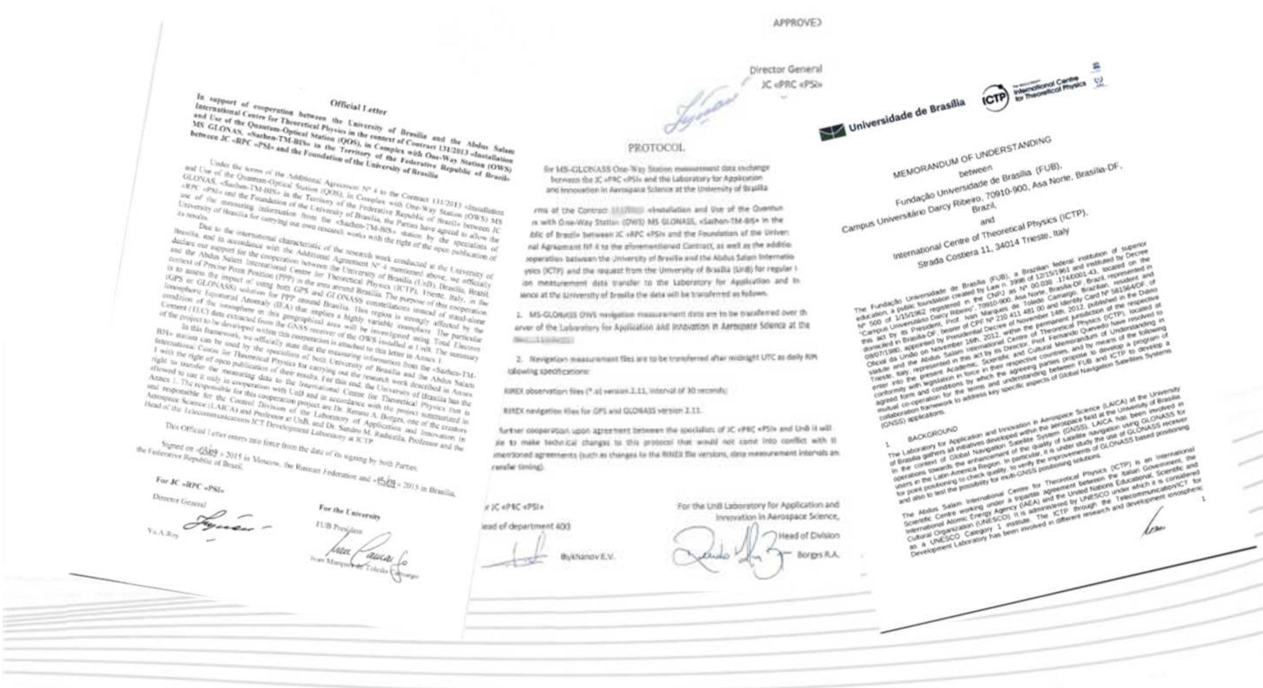
Aerospace Administrative Structure



Cooperation Between UnB and ICTP

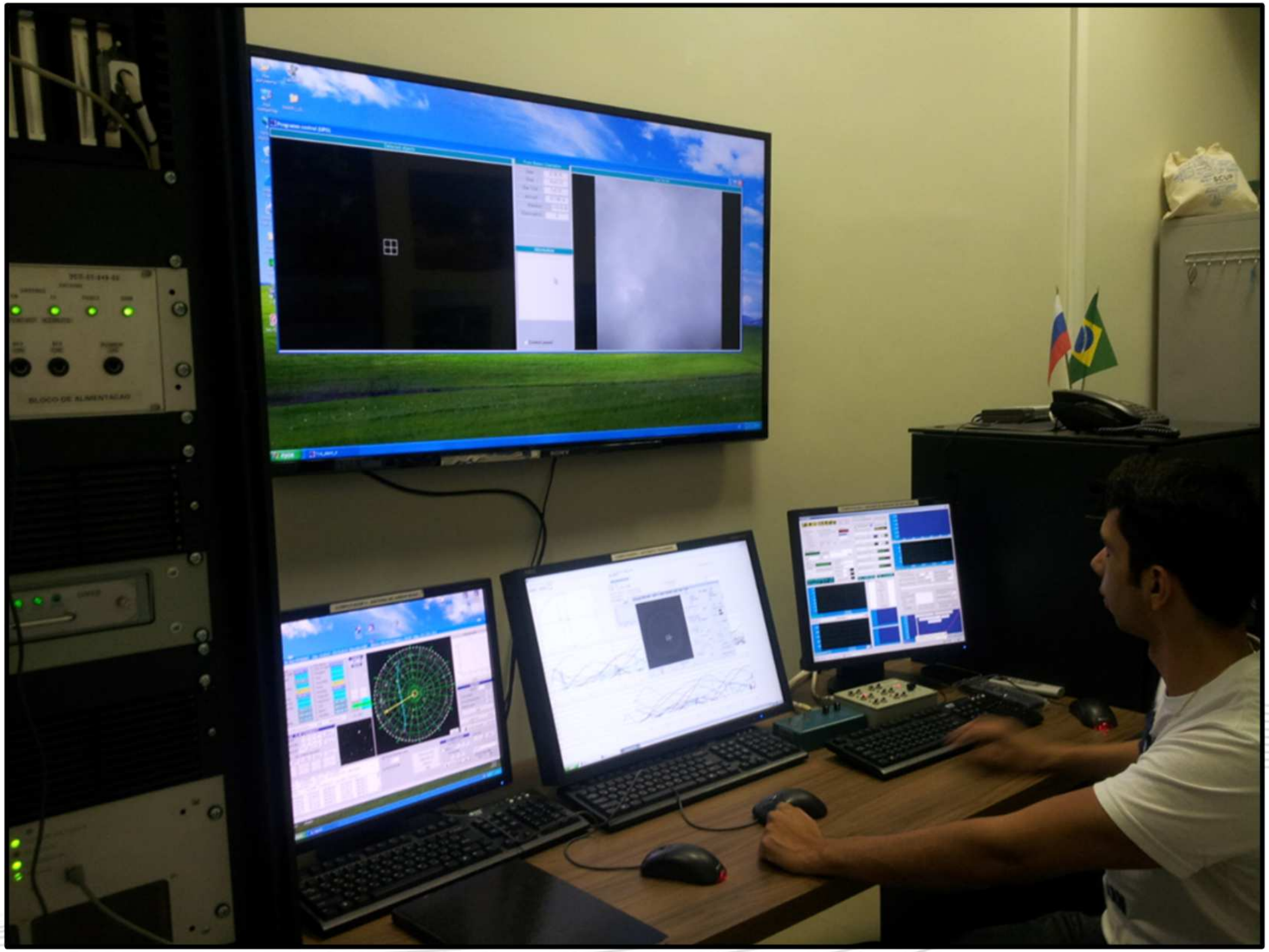
Timeline Overview:

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



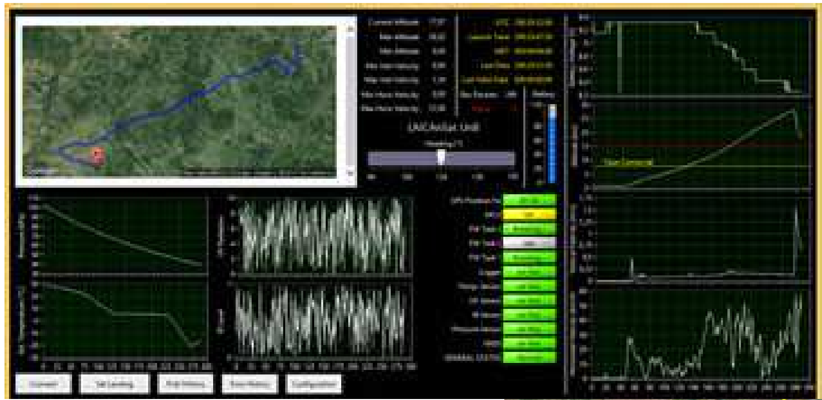
Technical Room

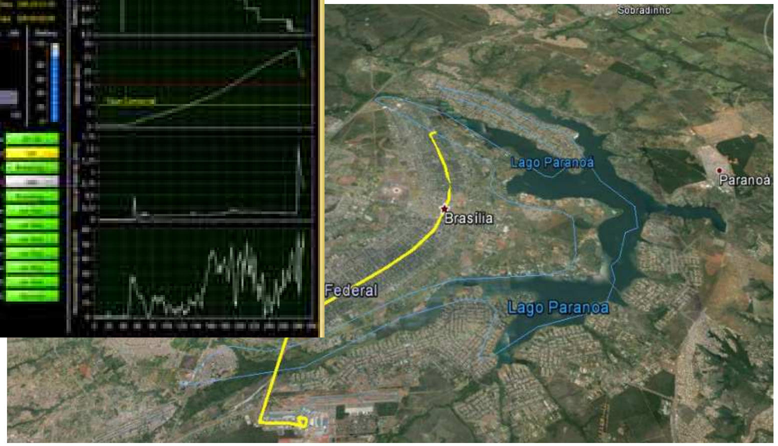
Laser operation and data transfer server room

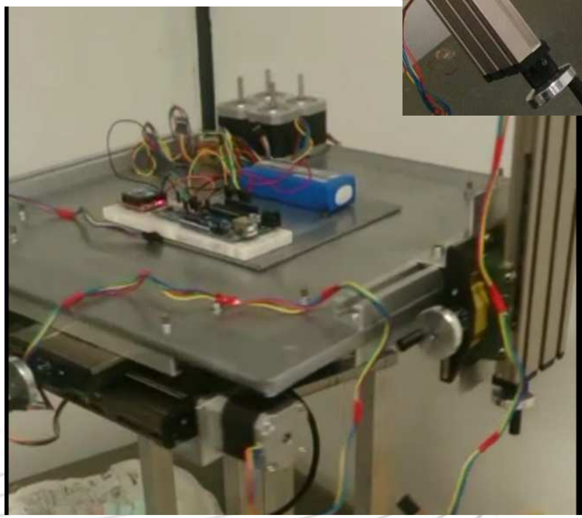


Associated Research and Development

Possible applications and test facilities:







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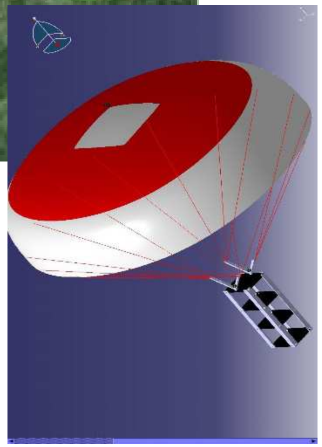
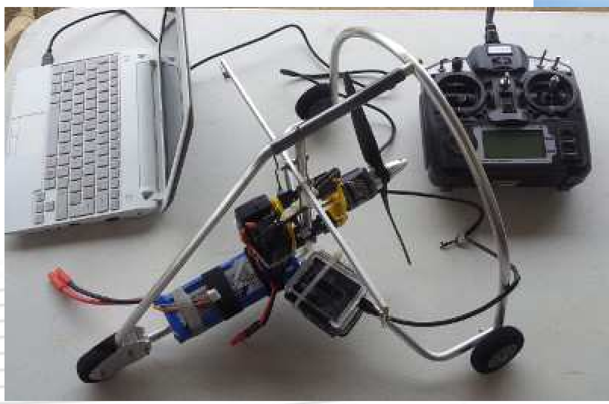




Associated Research and Development

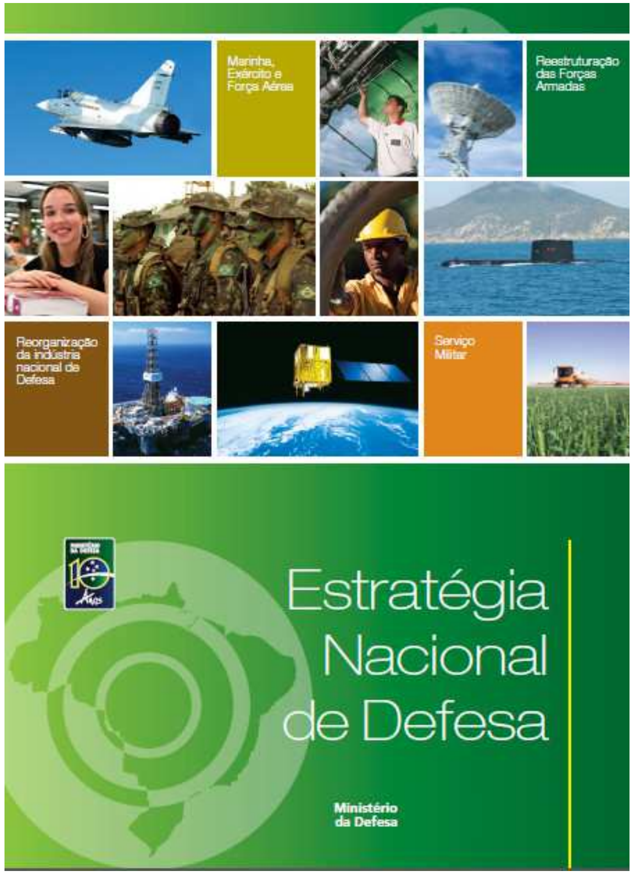
Topics for investigations :

•uBlox M8 GNSS single frequency module:

- Iono correction models;
- Impact point prediction;
- Attitude determination and control.

•MS-GLONASS IBPA.464346.003 dual frequency receiver:

- Precise Point Positioning (PPP).

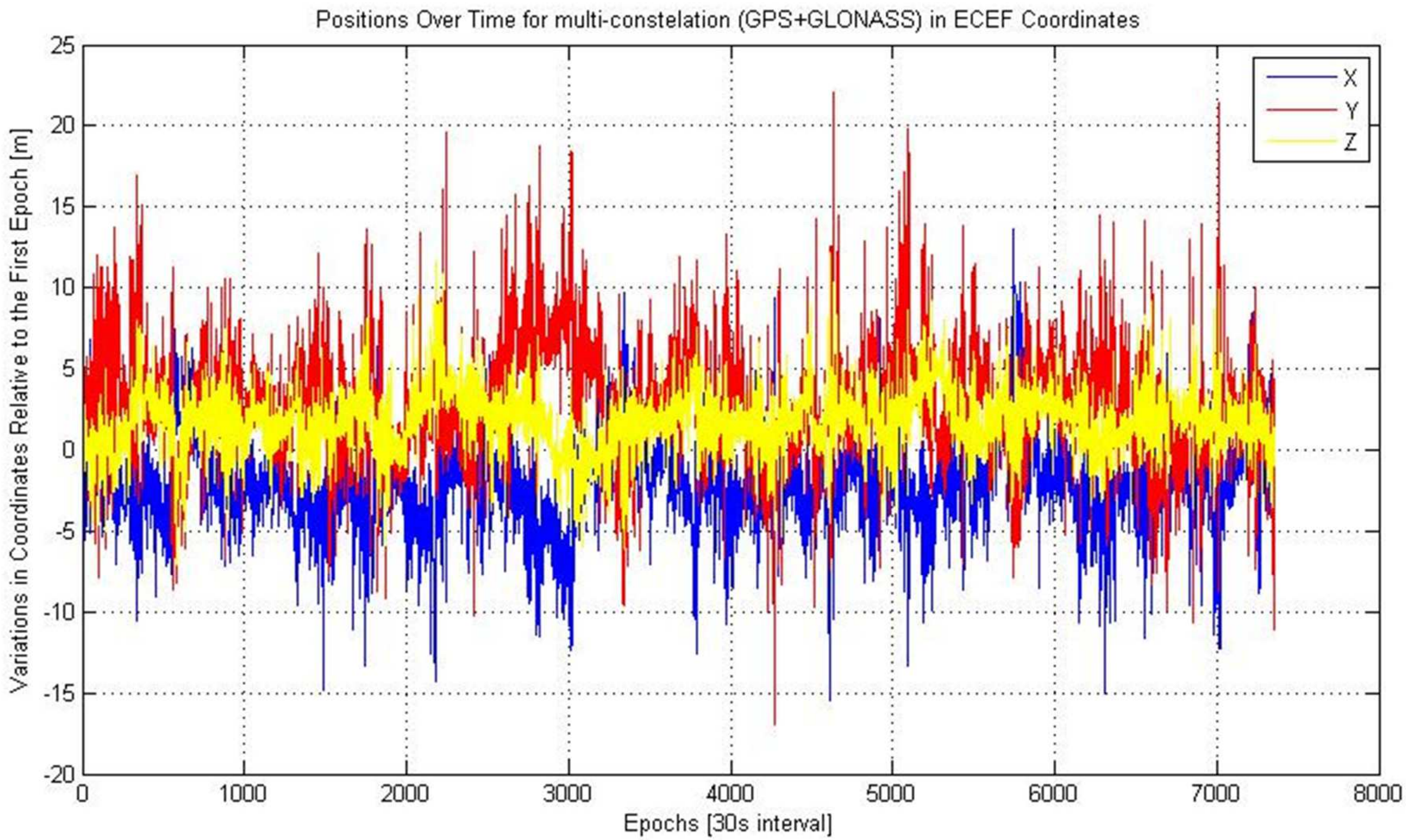


Brazilian national defense strategy :

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

Associated Research and Development

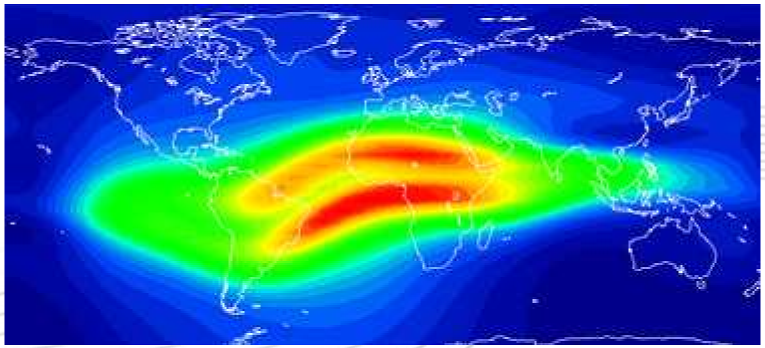
Preliminaries results - Point positioning using uBlox M8 module.



PPP Project - Objective

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

Precise orbit and clock information

+

User satellite tracking information

+

Additional error modelling

=

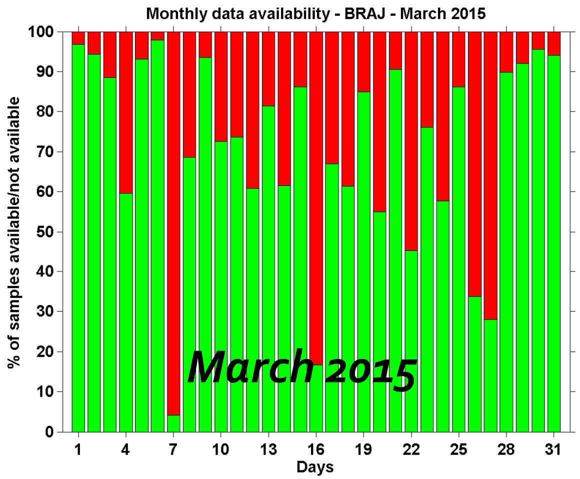
dm- to cm-lever user position estimates

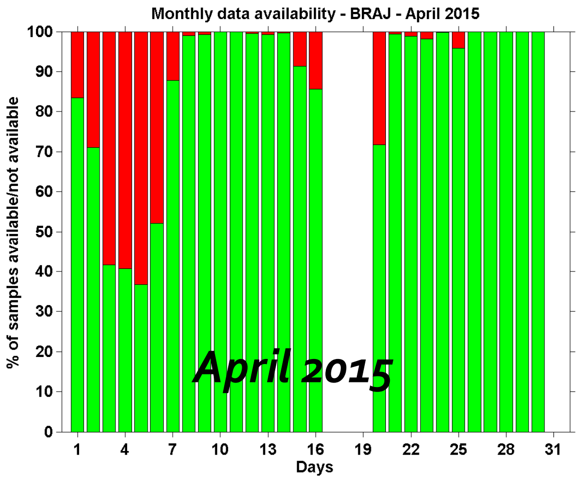
<u>Months analysed</u>

March, April, October 2015 (equinoctial period)

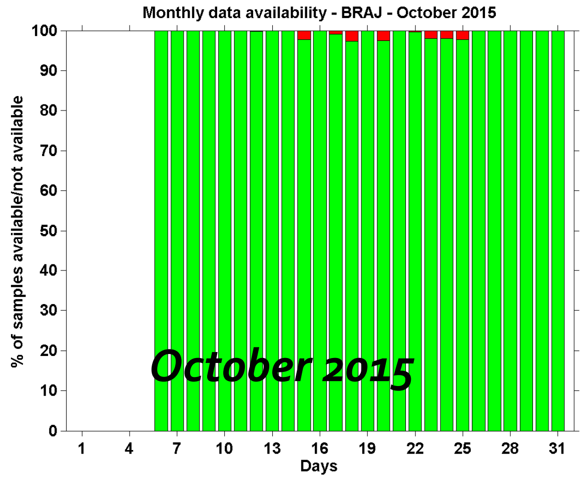
June, July 2015 (solstitial period)

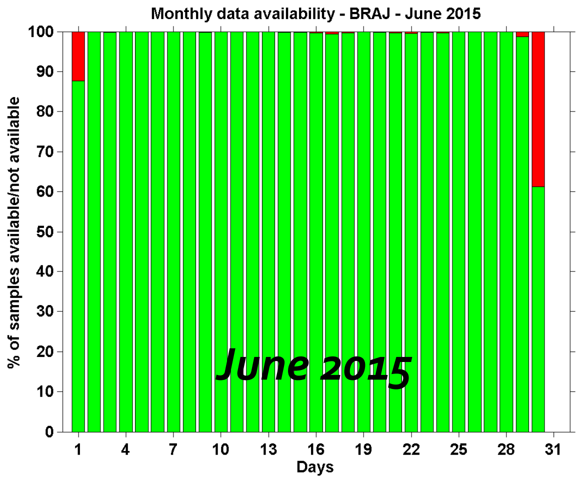
BRAJ Monthly Availability

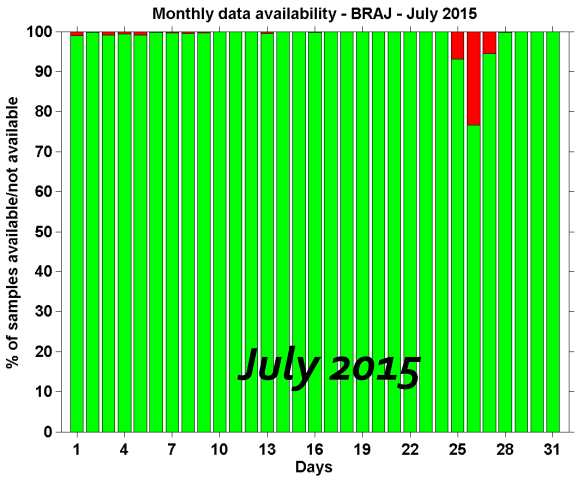




Days with data samples < 85% not considered for the analysis



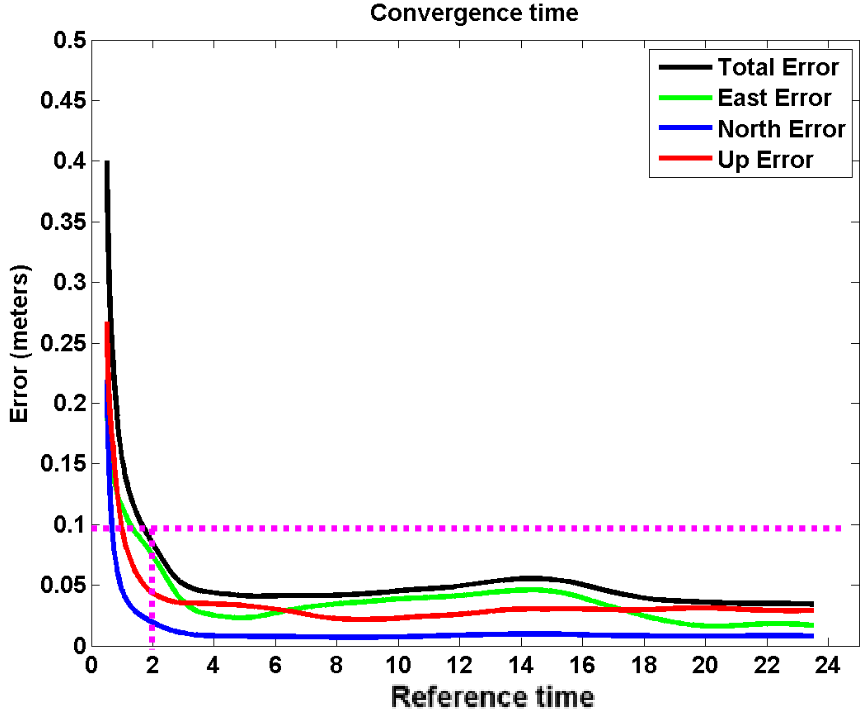




Monthly values		North Error (m)	East Error (m)	Up Error (m)
March 2015	G	0.007 ± 0.183	0.024 ± 0.115	0.127 ± 0.402
	M	0.026 ± 0.113	0.027 ± 0.076	0.081 ± 0.252
April 2015	G	0.035 ± 0.115	0.034 ± 0.095	0.109 ± 0.355
	M	0.040 ± 0.100	0.021 ± 0.067	0.056 ± 0.225
June 2015	G	0.037 ± 0.100	0.010 ± 0.037	0.009 ± 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

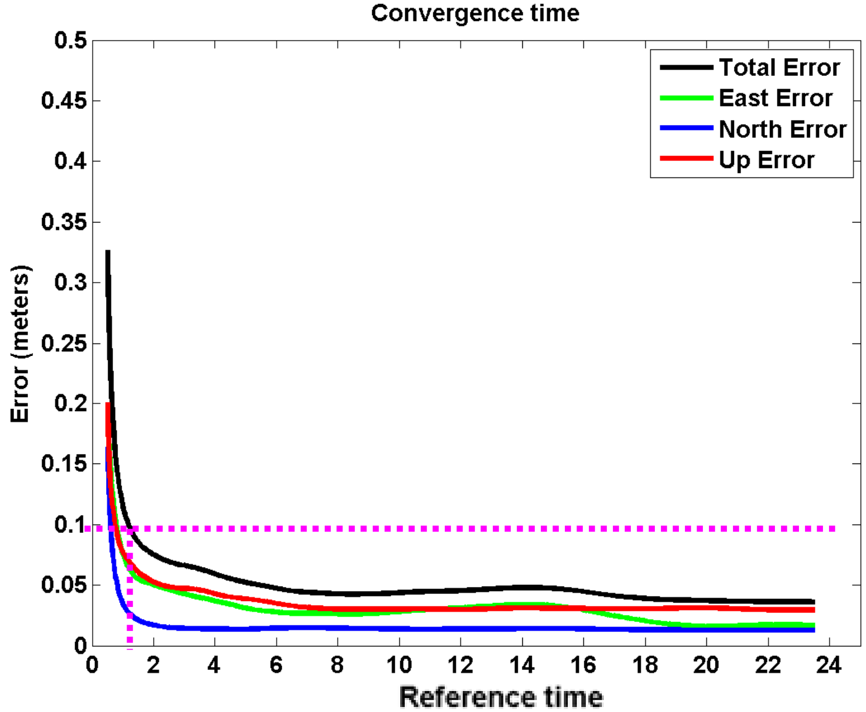
G – GPS, M – mixed (GPS + GLONASS)

Convergence time comparison



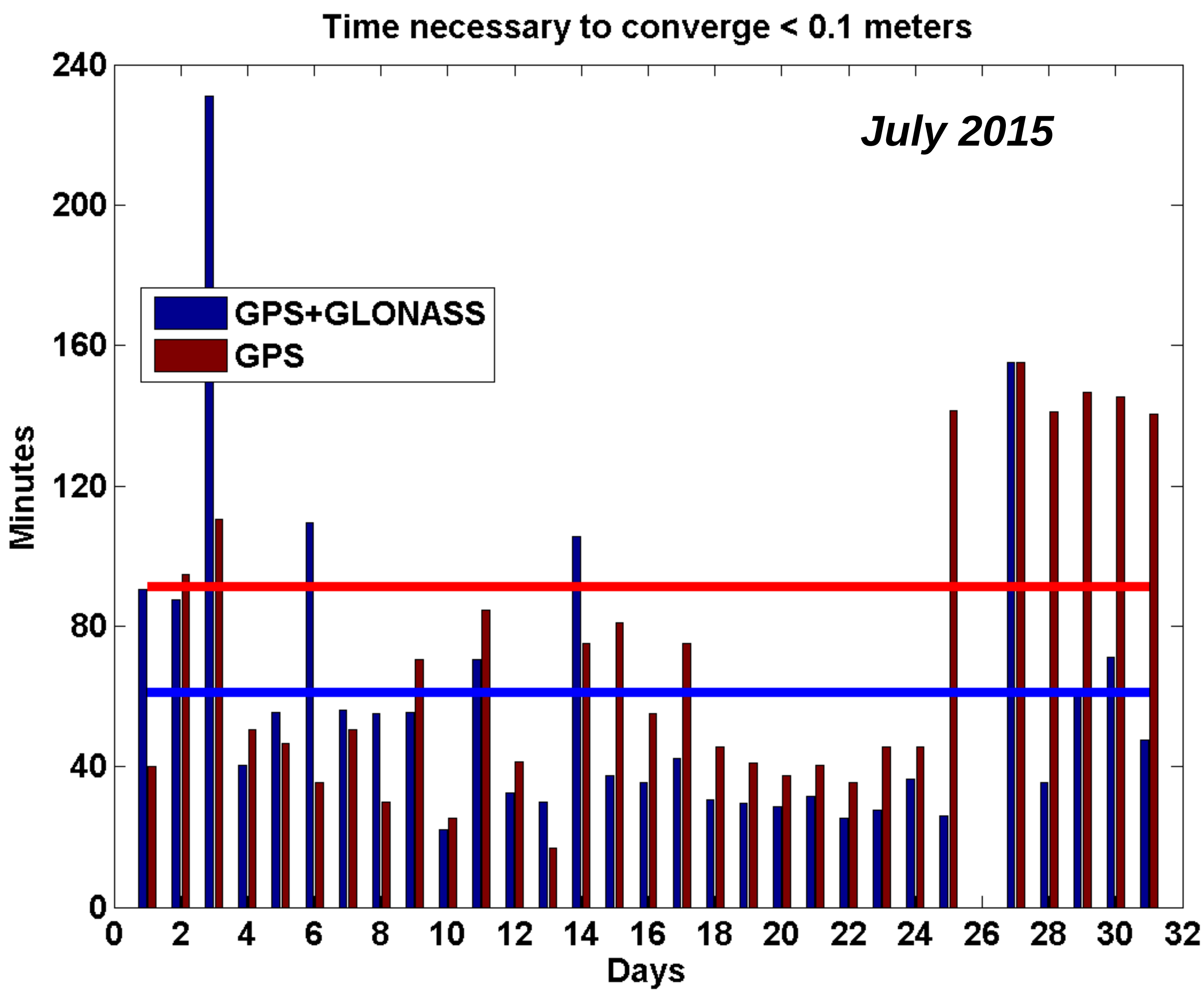
July 2015

GPS

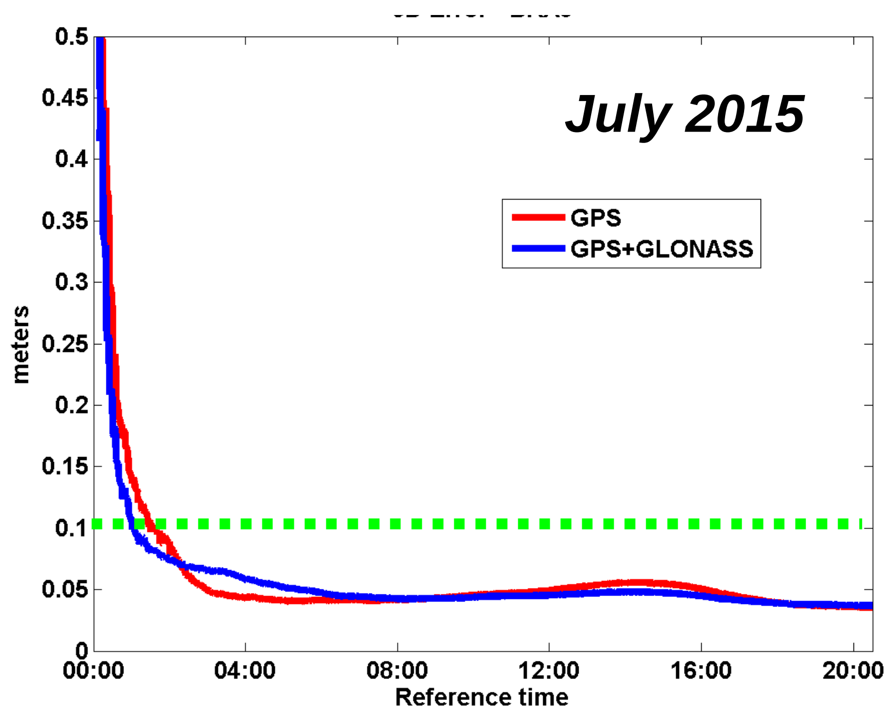


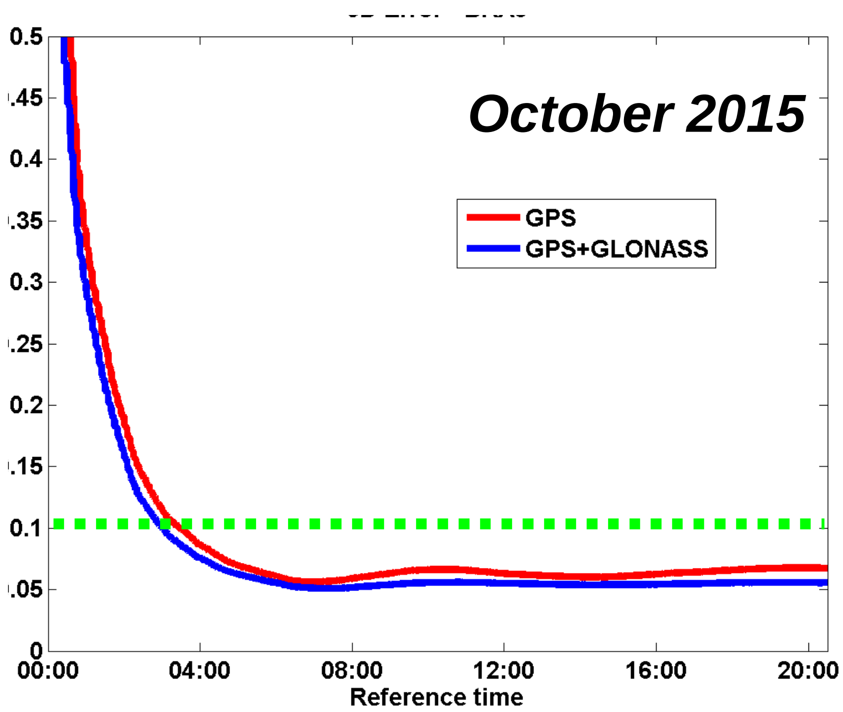
July 2015

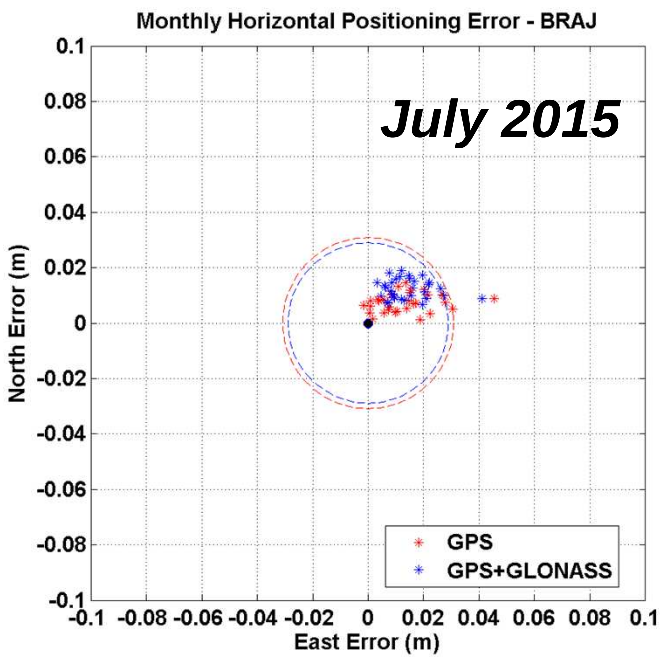
GPS/GLONASS



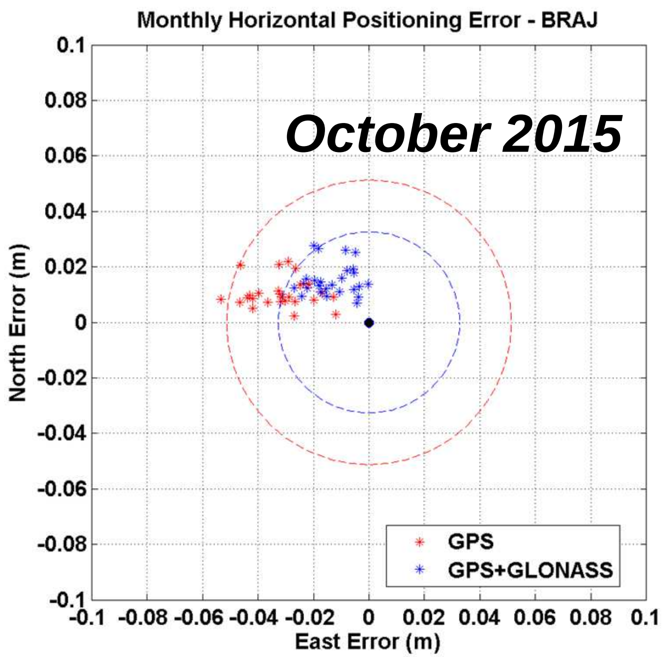
Time necessary to converge < 0.1 meters
July 2015
GPS+GLONASS
GPS
Minutes
Days
0
40
80
120
160
200
240
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32



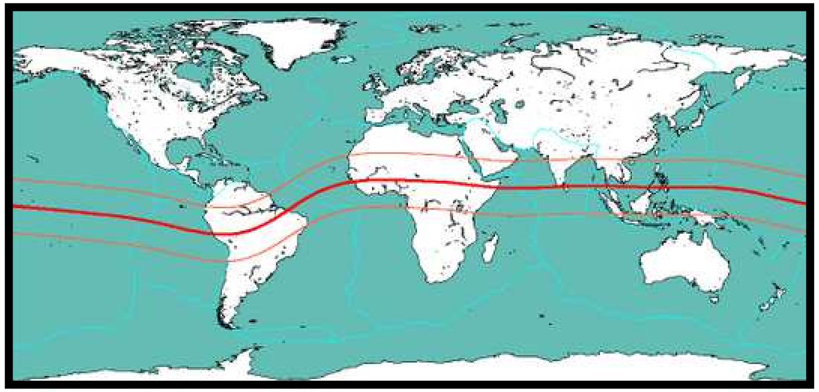




Position Accuracy



The IEA is characterized by two crests of electron density at ± 20º North and South of the geomagnetic equator and a minimum at this Equator.



- **IEA** presents strong diunal, 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).

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

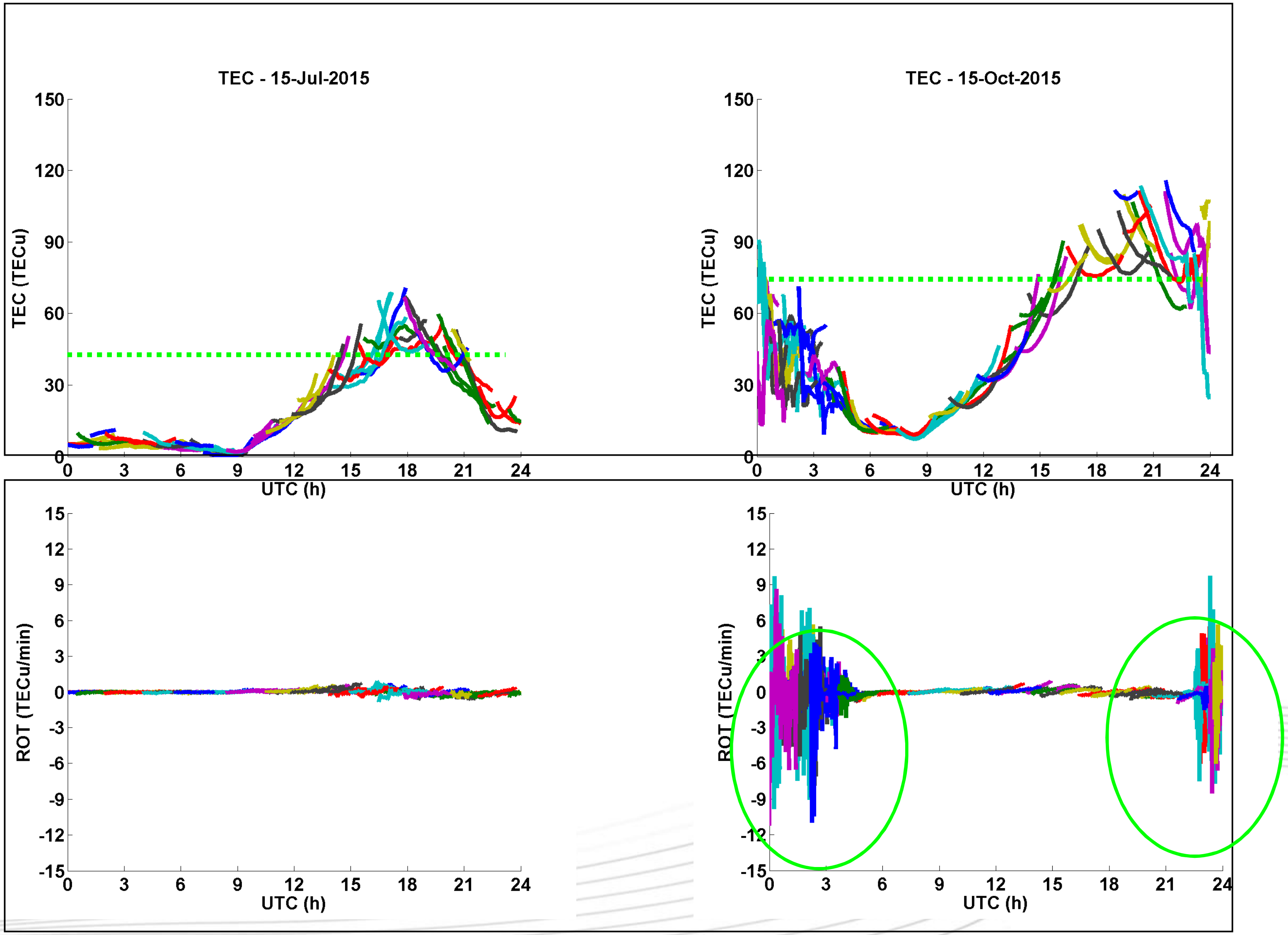
$$ROT = \frac{STEC_{k+1} - STEC_k}{time_{k+1} - time_k}$$

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

15 July 2015 *15 October 2015*

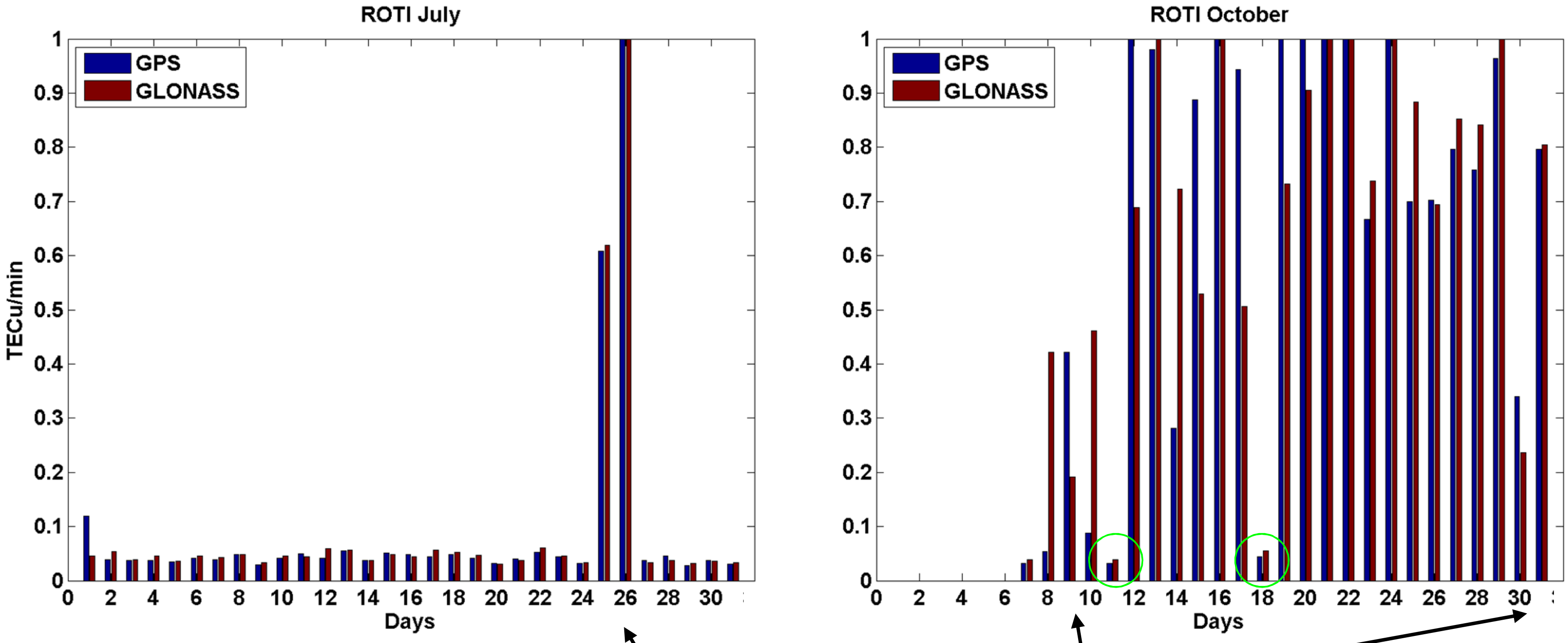
TEC

ROT



Post Sunset Monthly ROTI

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



Presence of Irregularities

Some Final Remarks

Results preliminary considerations (PPP)

- PPP results indicate an improvement in accurary 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;

The Abdus Salam International Centre for Theoretical Physics

UnB

Thank You For Your Attention!

Acknowledgements:

JC "RPC "PSI"

ROSCOSMOS

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UnB/DPP

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