Investigation on the performance of a low-cost single frequency GNSS receiver for PPP application

C. Paparini, R. A. Borges, X. Otero Villamide, A. Kashcheyev, S. M. Radicella, B. Nava

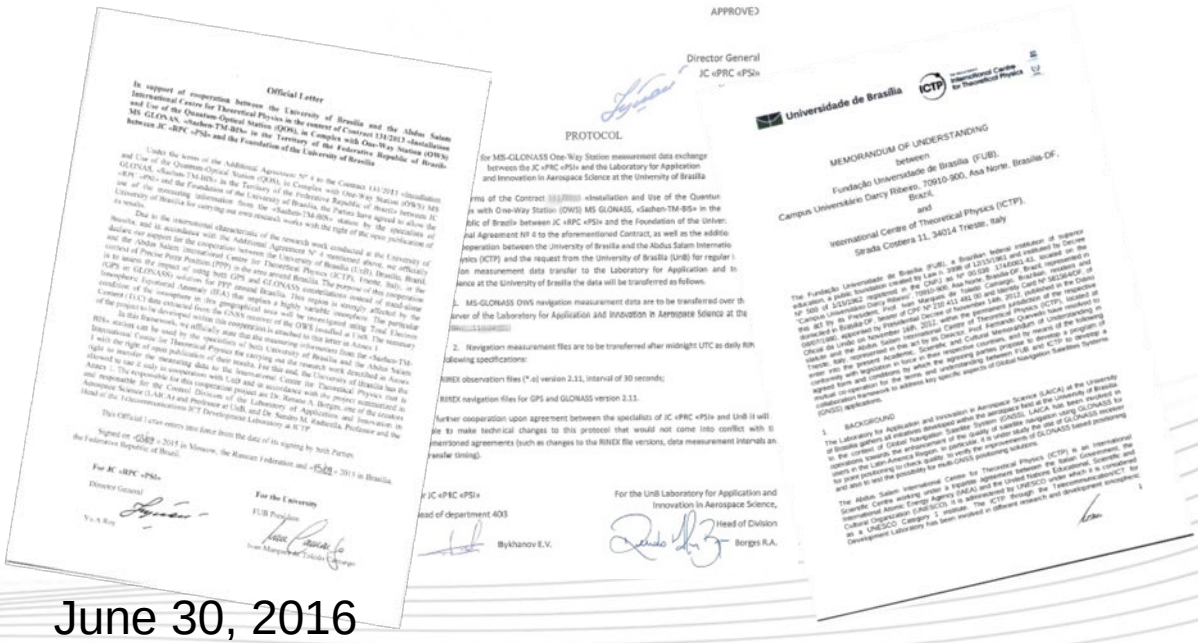
Emails: paparini@ictp.it, raborges@ene.unb.br, xotero_v@ictp.it, rsandro@ictp.it, bnava@ictp.it

Beacon Satellite Symposium
Trieste, July 2016

Cooperation Between UnB and ICTP

Timeline Overview:

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



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;

Memorandum of Understanding

The main scientific aspect of this cooperation is to assess the impact of using both GPS and GLONASS constellations instead of stand-alone (GPS or GLONASS) solution for Precise Positioning around Brasilia with data extracted from the GNSS receiver of the One-Way Station (OWS) MS GLONASS, «Sazhen-TM-BIS» installed at University of Brasilia.

Cooperation based team building activities

•Exchange of information between those responsible for scientific research in the field;

•Elaboration of research programs and work plan for cooperation activity;

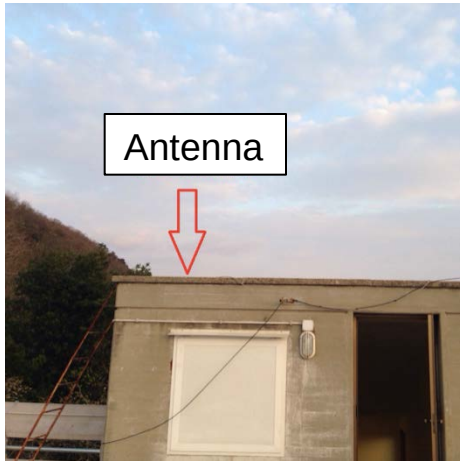
•Exchange of equipment and bibliographical material;

•Exchange of pedagogical experience and information;

•Exchange of professors, students, specialists and technical servers;

Performance comparison of different absolute positioning techniques (PPP) using a single-frequency mass-market low-cost Global Navigation Satellite System (GNSS) receiver – uBLOX NEO – M8T

Locations



Trieste, Italy - UBXT

Antenna

Brasilia, DF, Brazil - UBXB

Single-Frequency PPP Principles

$$C_1 = \rho_r^s + c(dt_r - dt^s + T_{gd}) + d_{orb} + d_{trop} + d_{ion} + d_{rel} + \varepsilon(C_1)$$

$$\Phi_1 = \rho_r^s + c(dt_r - dt^s) + d_{orb} + d_{trop} - d_{ion} + d_{rel} + d_{w1} + \lambda_1 N_1 + \varepsilon(\Phi_1)$$

$$C_1 = \rho_r^s + c(dt_r + T_{gd}) + d_{trop} + d_{ion} + \varepsilon(C_1)$$

$$\Phi_1 = \rho_r^s + cdt_r + d_{trop} - d_{ion} + \lambda_1 N_1 + \varepsilon(\Phi_1)$$

$$C_1 = \rho_r^s + cdt_r + d_{ion} + \varepsilon(C_1)$$

$$\Phi_1 = \rho_r^s + cdt_r - d_{ion} + \lambda_1 N_1 + \varepsilon(\Phi_1)$$

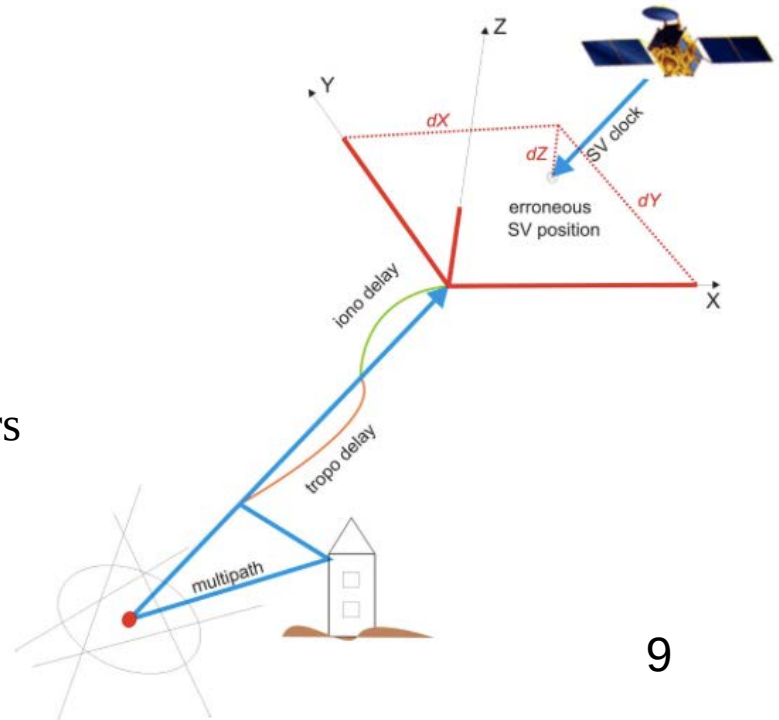
In the case of single frequency observations the user needs additional information on ionosphere, since the ionospheric influence cannot be eliminated as in the case of dual frequency measurements. Hence the derivation of accurate TEC models is a necessity towards enhanced position accuracy for single frequency PPP.

PPP Benefits

- Single receiver operation (low-cost).
- Not limited by baseline length as relative techniques.
- Independence from GNSS reference stations.
- Can be applied for static and kinematic platforms.

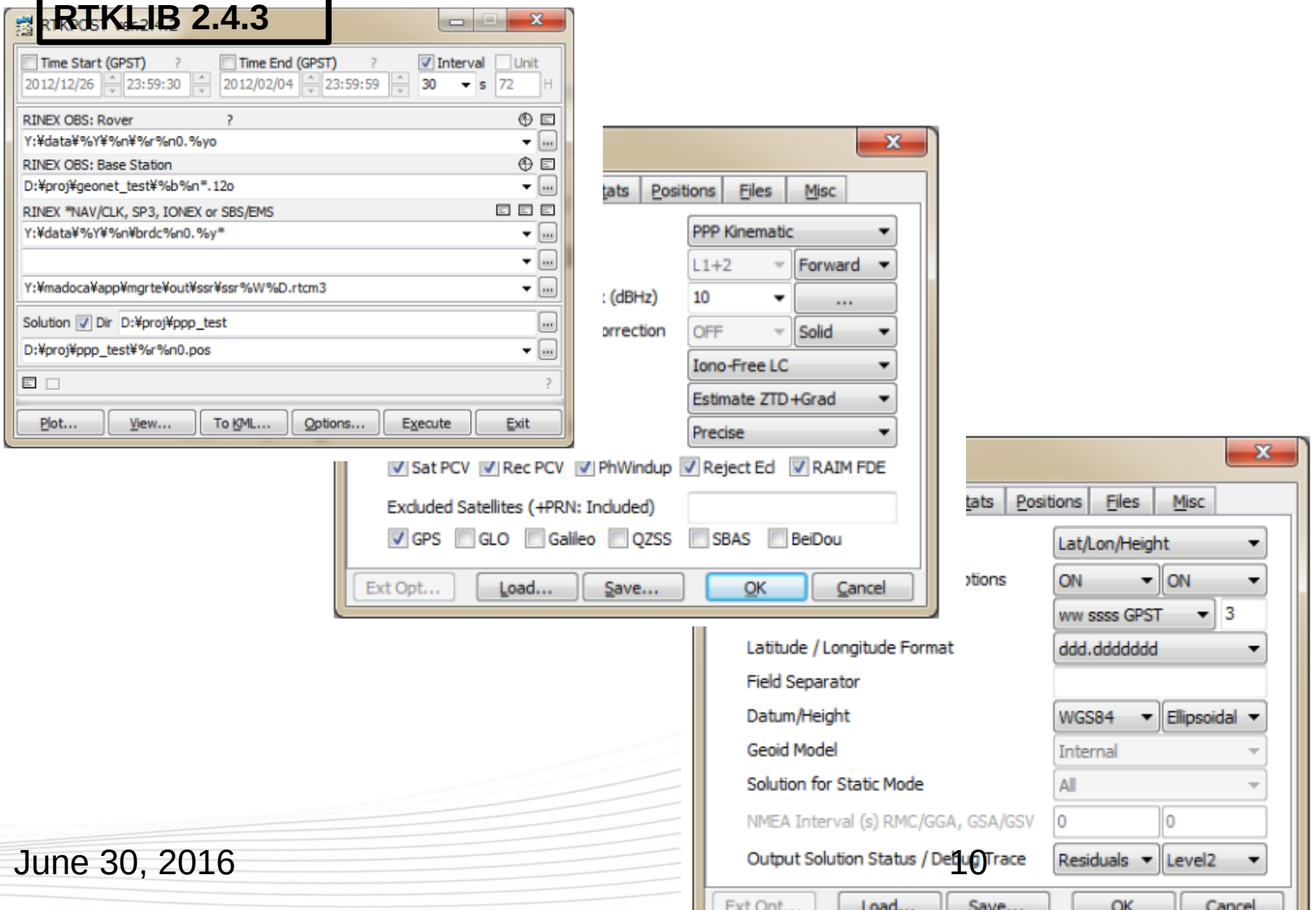
Errors affecting the GNSS observations

- Satellite orbit and clock corrections, (provided by IGS)
- Relativistic effects
- Receiver and satellite antenna phase center offsets (provided by IGS or NGS)
- Satellite P1–P2 and P1-C1 differential code biases (DCBs) (provided by IGS)
- Receiver DCB (GPS receiver calibration in MPGPS™ or IGS)
- Phase wind-up
- Ionospheric refraction
- Tropospheric refraction
- Atmospheric Loading
- Ocean Loading
- Solid Earth Tides
- Earth Rotation Parameters



Software used (first approach)

RTKLIB 2.4.3



Ionospheric Correction used for single-frequency receivers

Computation of ionospheric corrections using an external model in order to remove the first order ionospheric error contribution.

In this research GNSS data has been corrected using:

- Klobuchar Ionospheric Model (GK, MK)
- Global Ionosphere Maps (GIMs) produced by IGS (GI, MI)
- NeQuick 2 Ionospheric Model (GN, MN)

NeQuick 2 is the latest version of the NeQuick ionosphere electron density model.

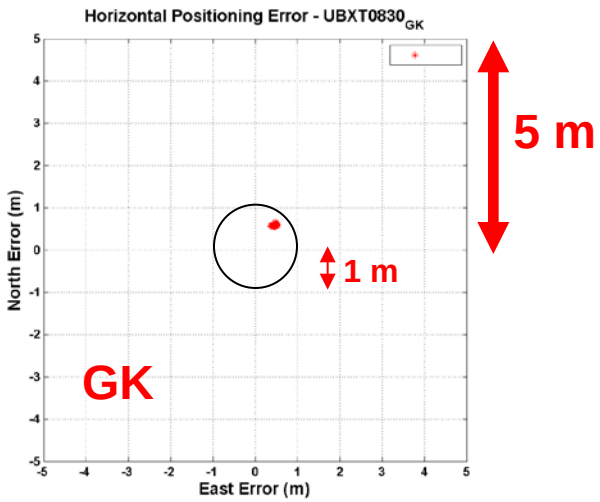
It is a climatological model that uses monthly average values of solar activity expressed by the 12-month running mean sunspot number R12 as a driver.

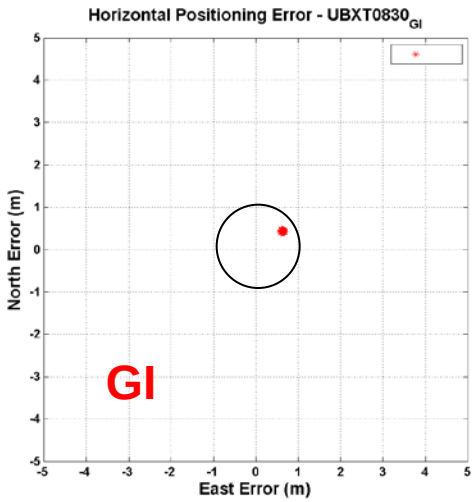
In this work, to switch from ionospheric climatology to weather and with the aim to apply NeQuick 2 model corrections in real-time, **the solar flux of the day before is used as a model input.**

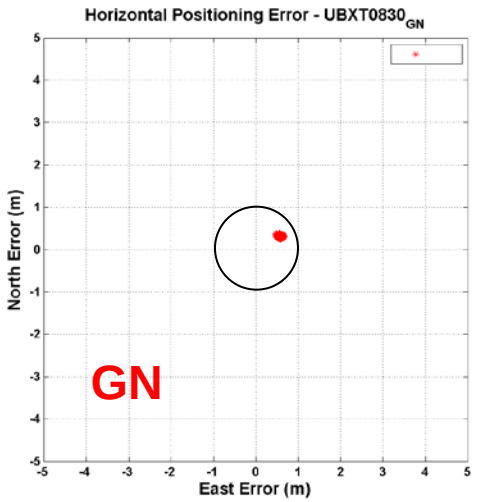
Preliminaries PPP results using u-blox NEO M8T in Trieste and Brasilia in March and April 2016

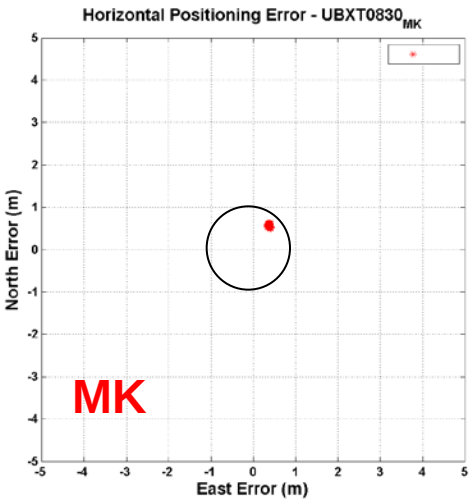
UBXT
Trieste - Italy

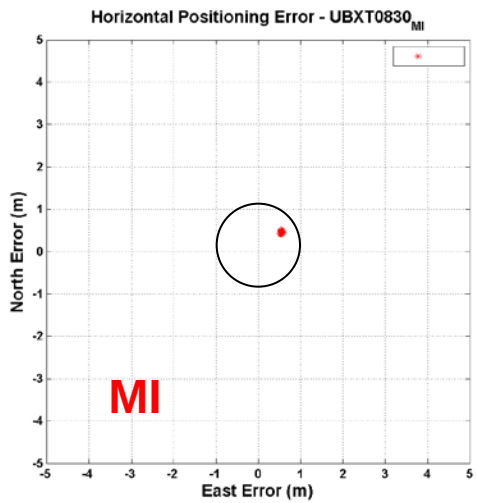
UBXT - GPS doy 83 - 23rd March 2016

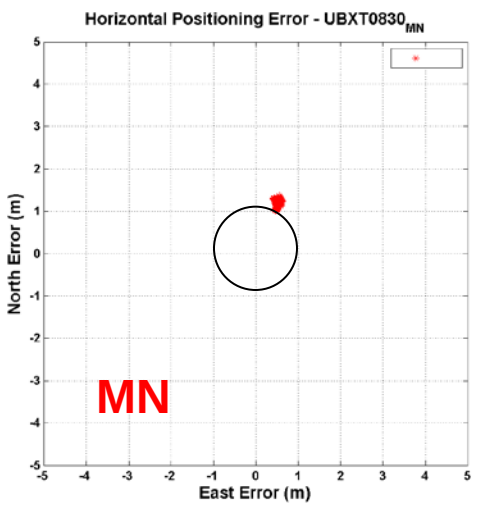




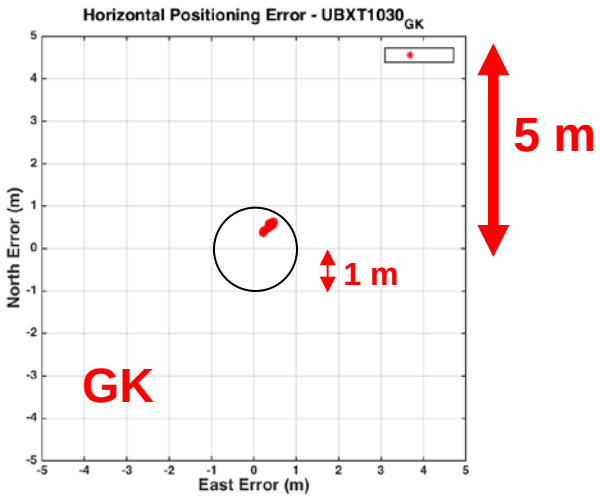


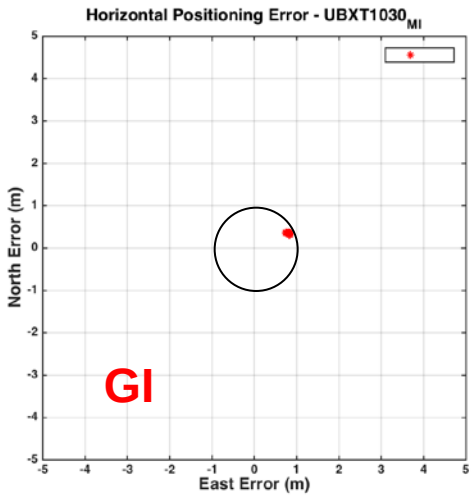


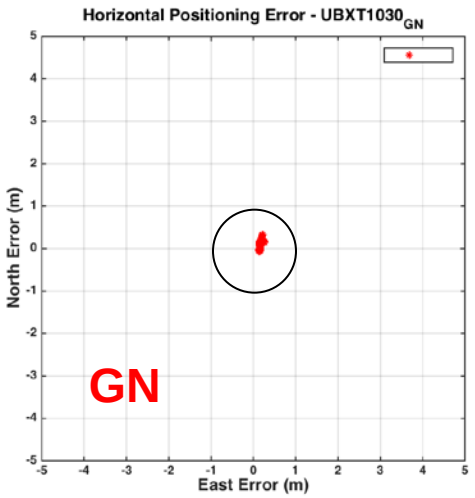


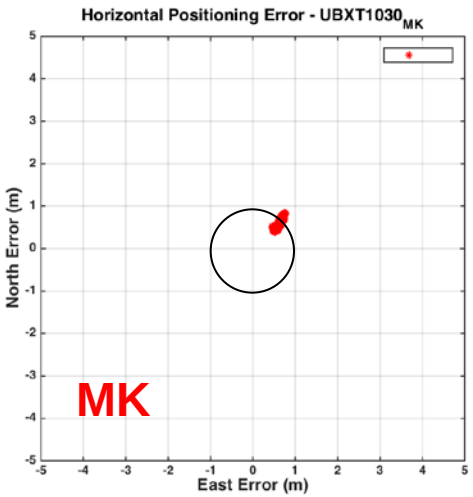


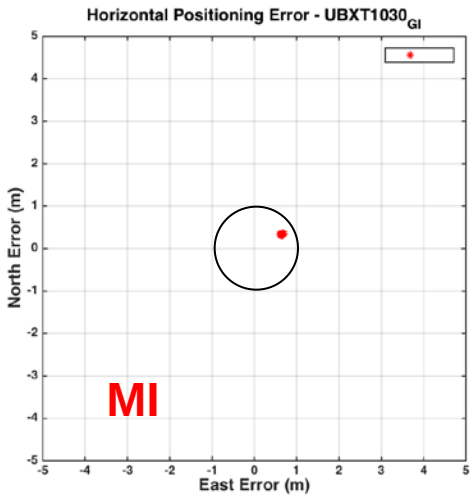
UBXT - GPS doy 103 – 12th April 2016

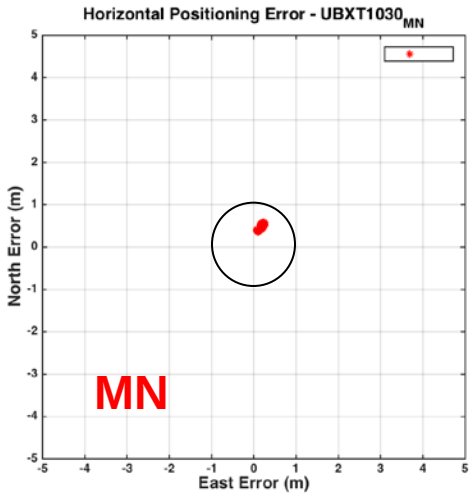






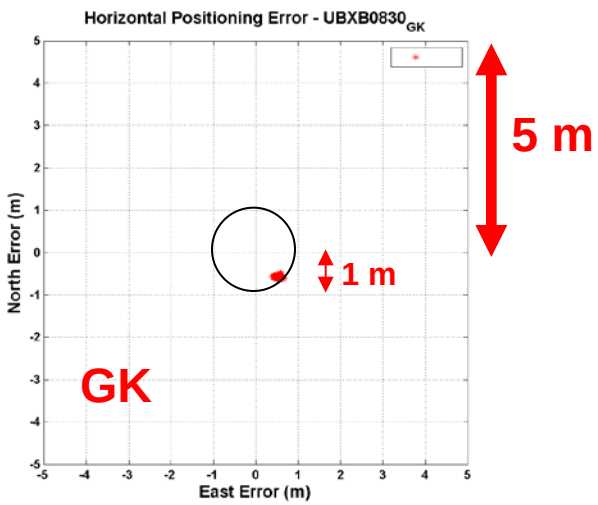


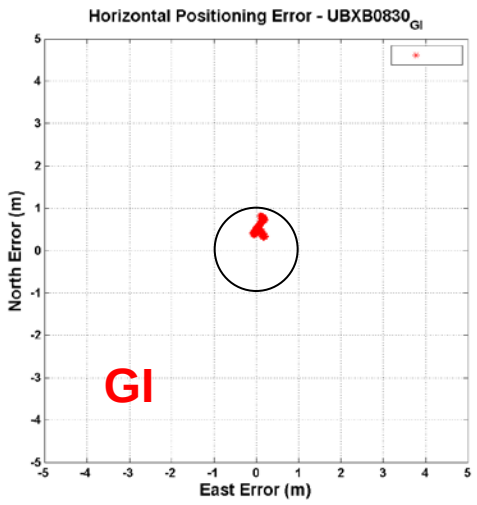


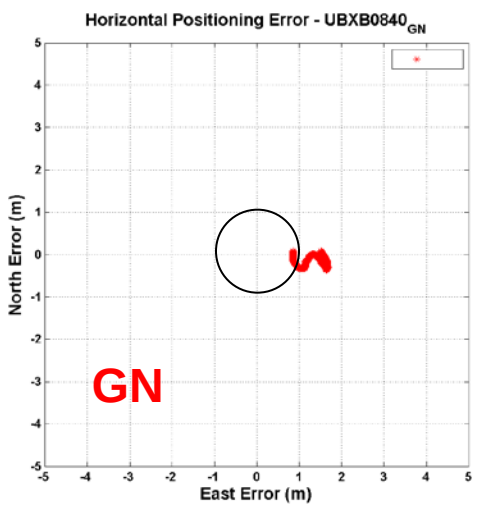


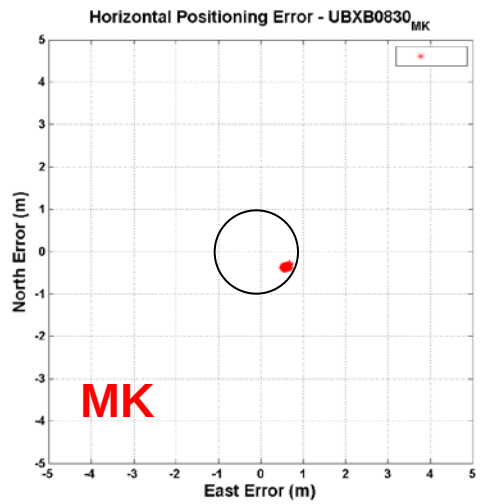
UBXB
Brasilia - Brazil

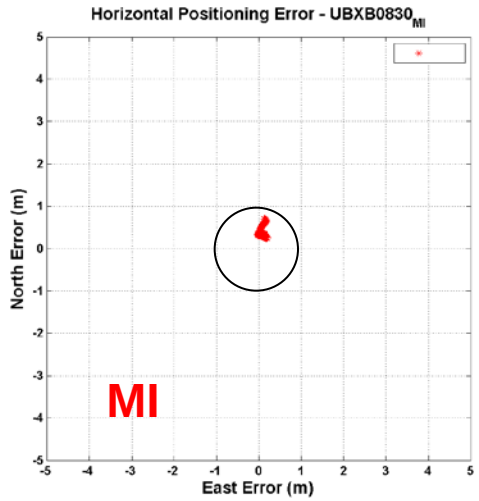
UBXB - GPS doy 83 - 23rd March 2016

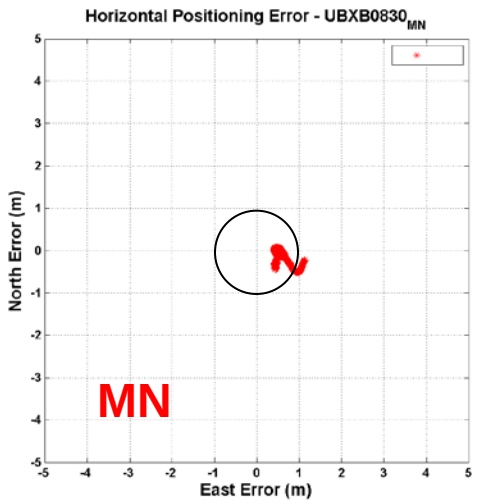




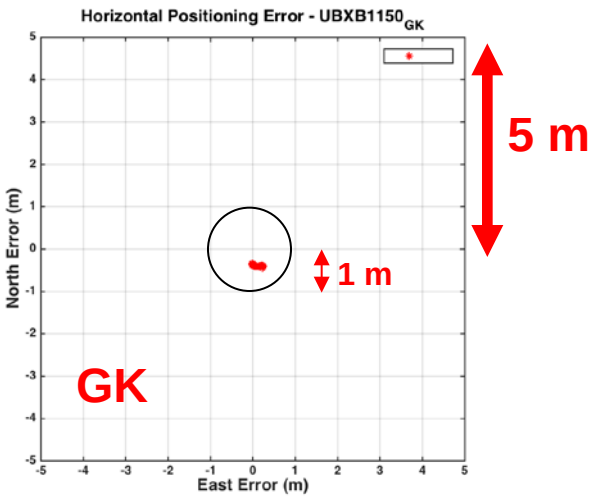


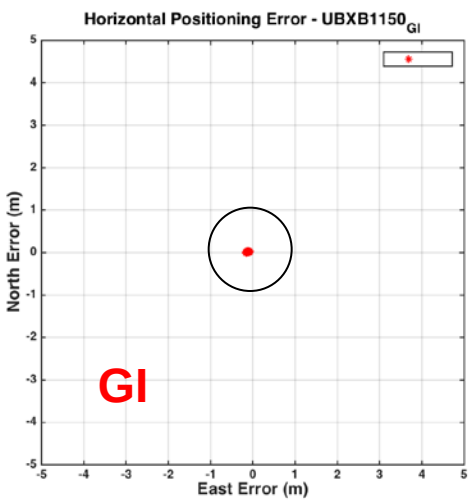


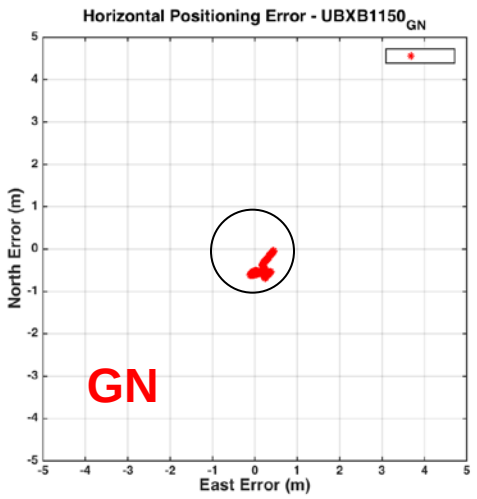


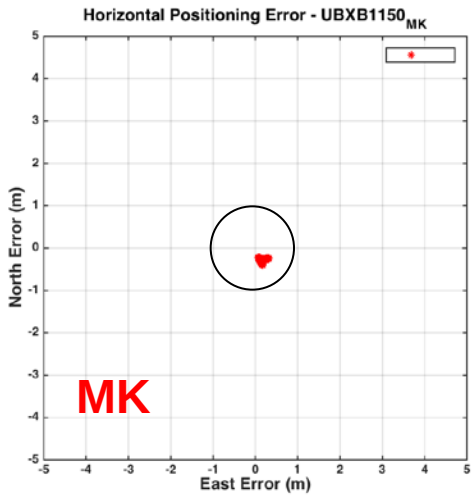


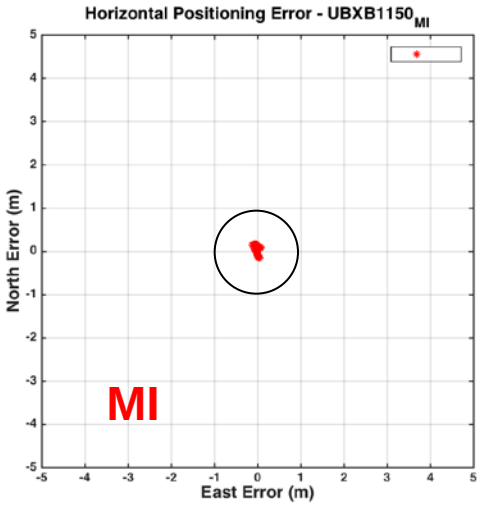
UBXB - GPS doy 115 - 24th April 2016

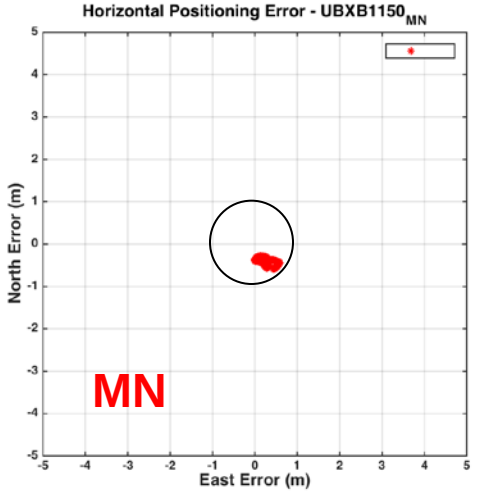




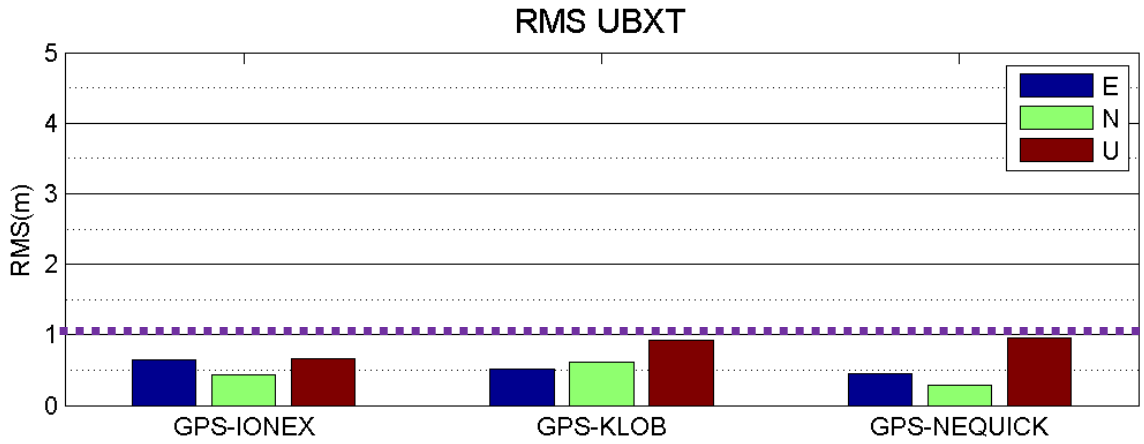




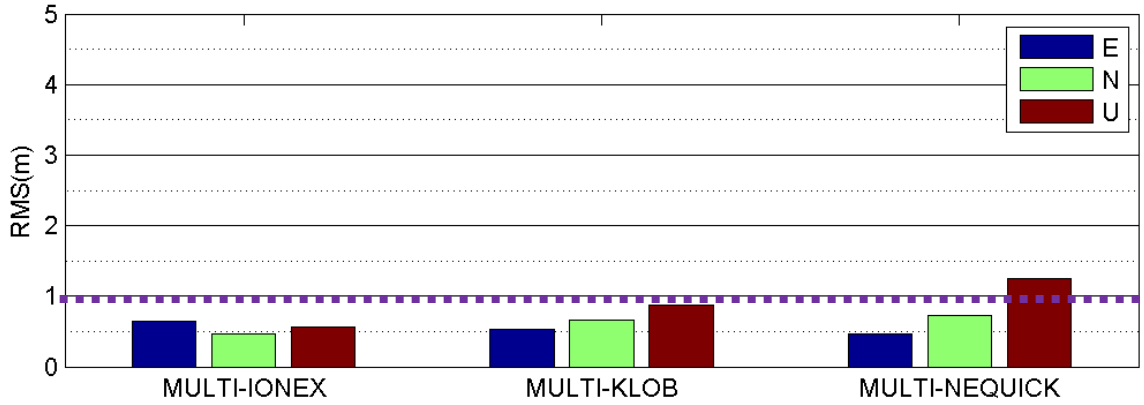




March 2016 Statistics – **UBXT**

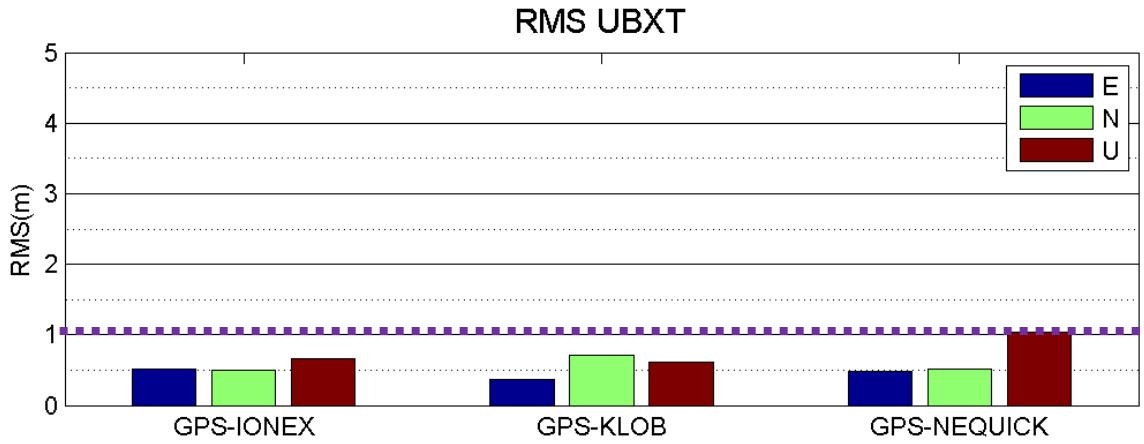


1 meter

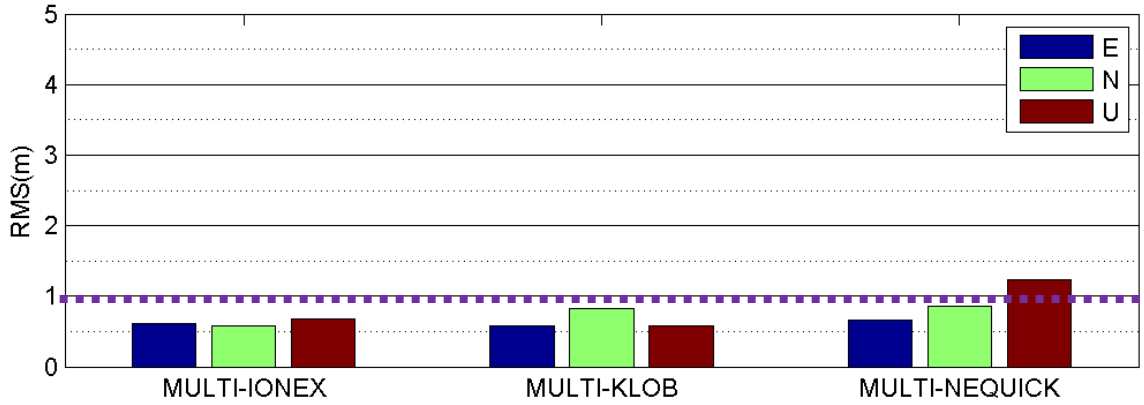


1 meter

April 2016 Statistics – **UBXT**

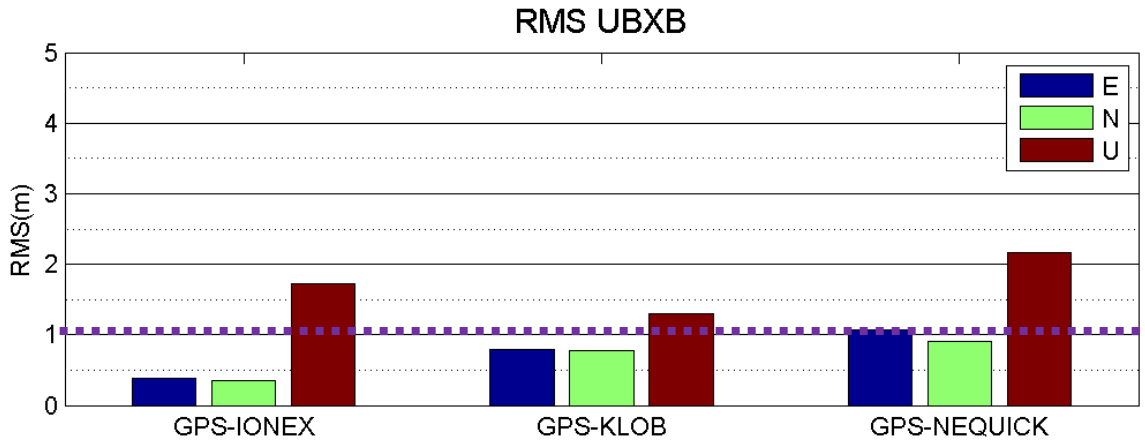


1 meter

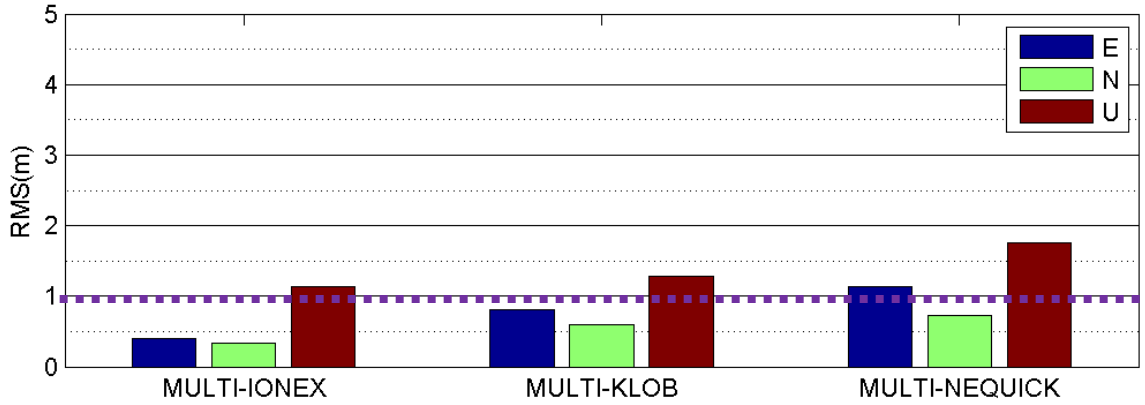


1 meter

March 2016 Statistics – **UBXB**

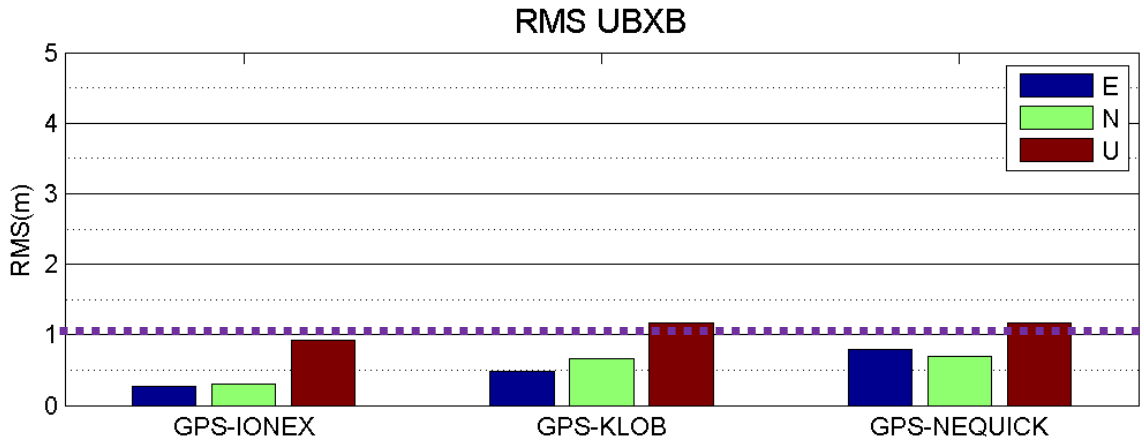


1 meter

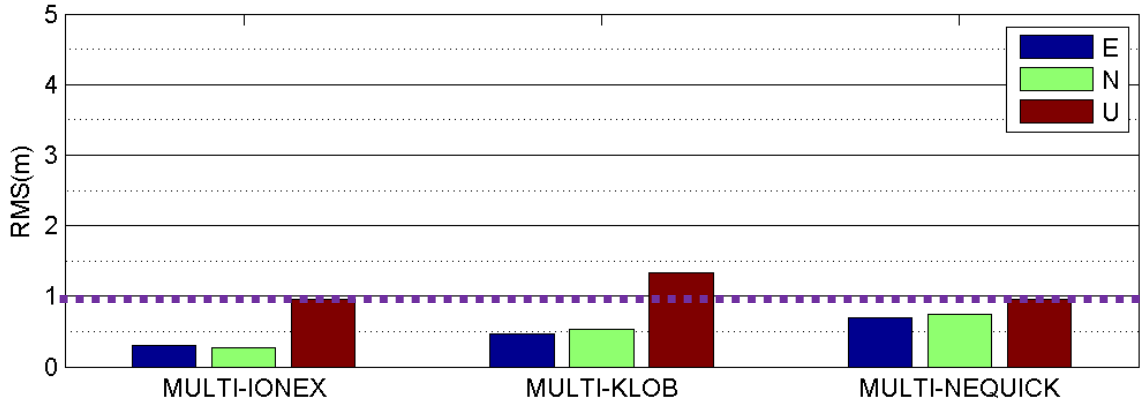


1 meter

April 2016 Statistics – **UBXB**



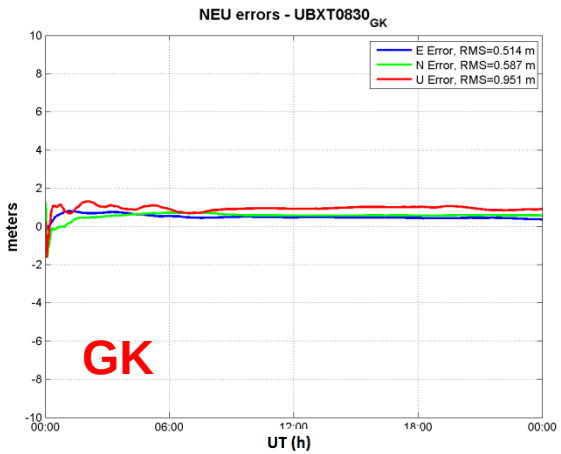
1 meter

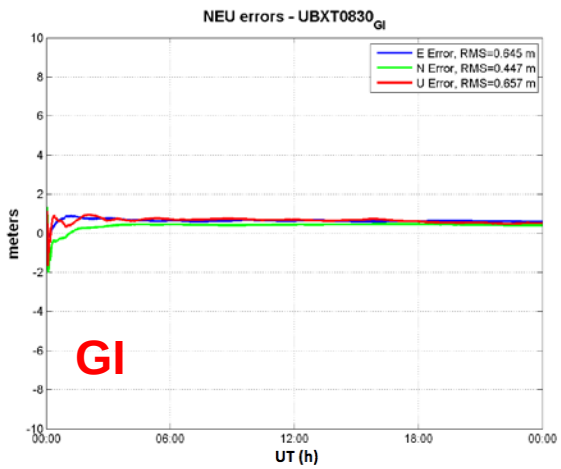


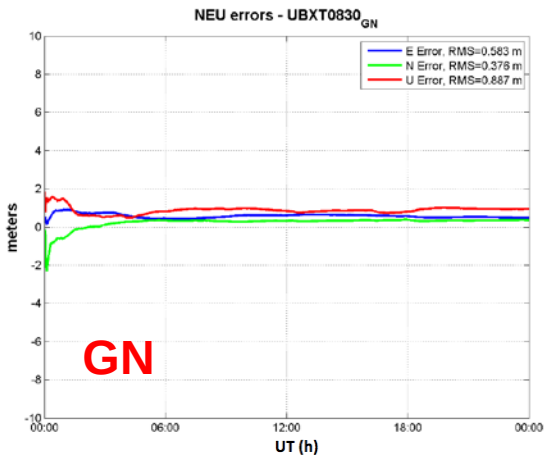
1 meter

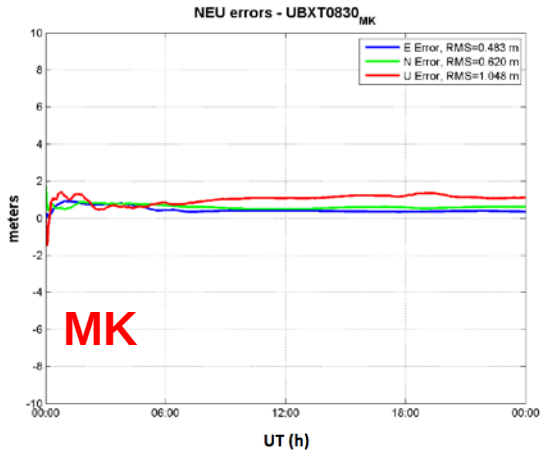
Scenarios Analysis

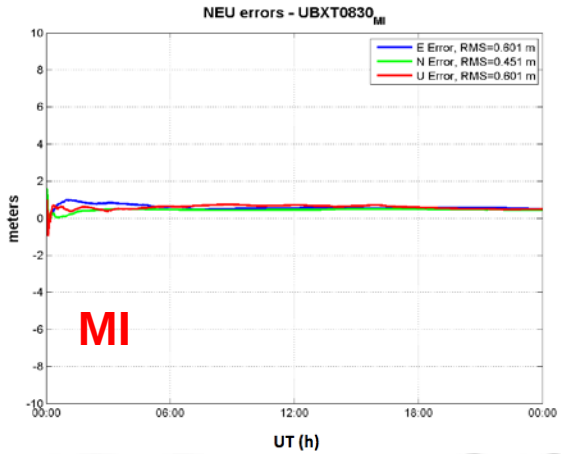
UBXT - Trieste - session 00:00

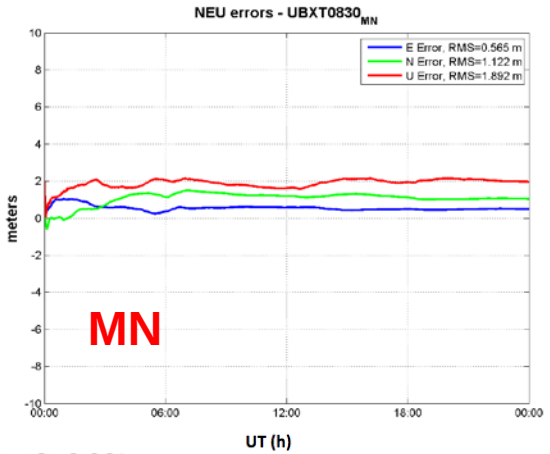






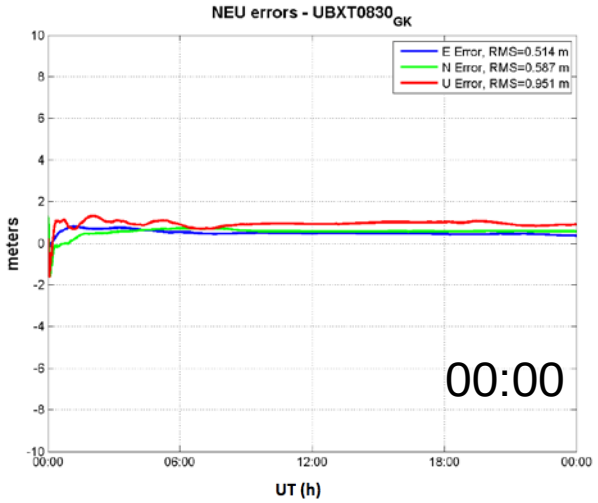


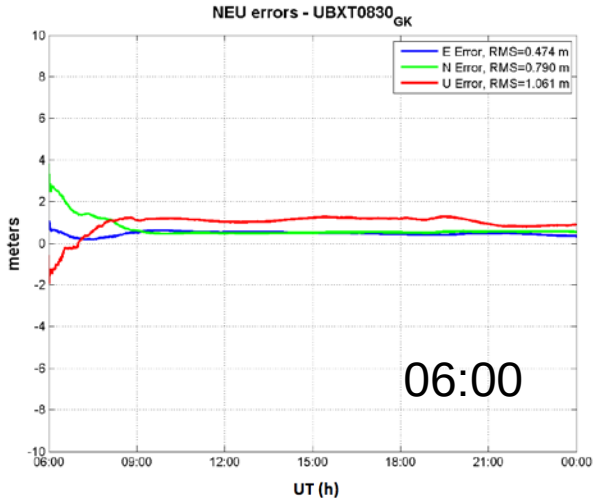


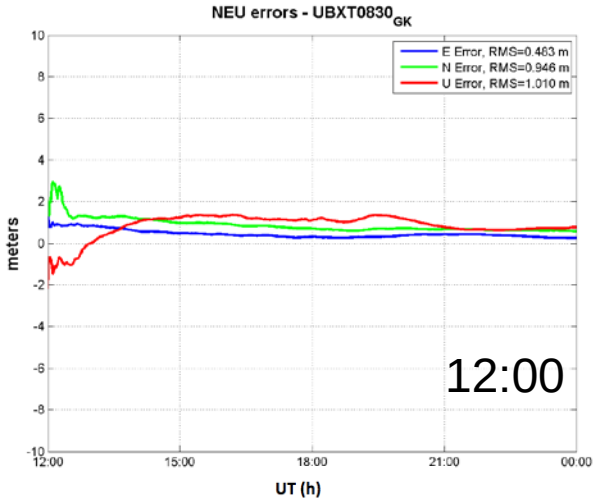


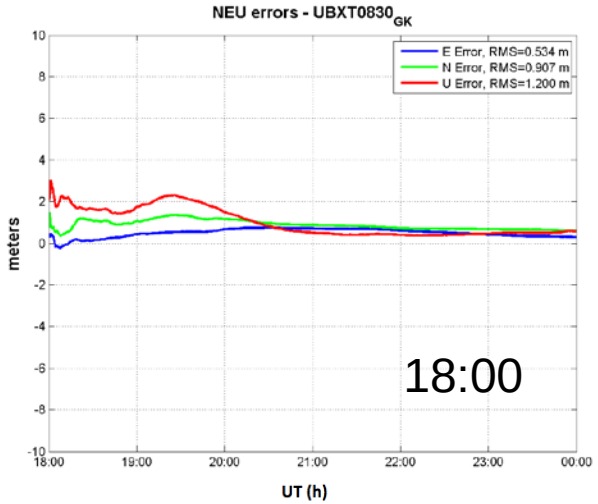
GPS doy 83 – 23th March 2016

GPS only - Klobuchar for different starting time sessions – **UBXT**



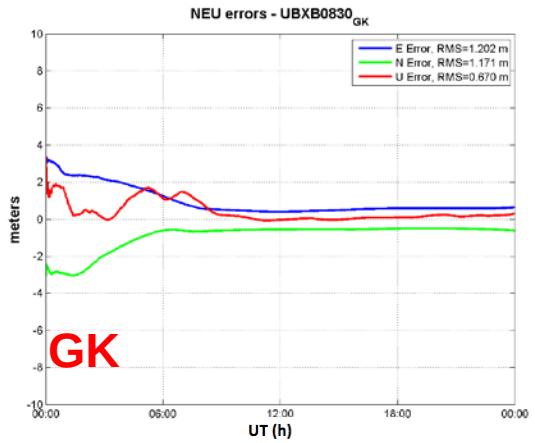


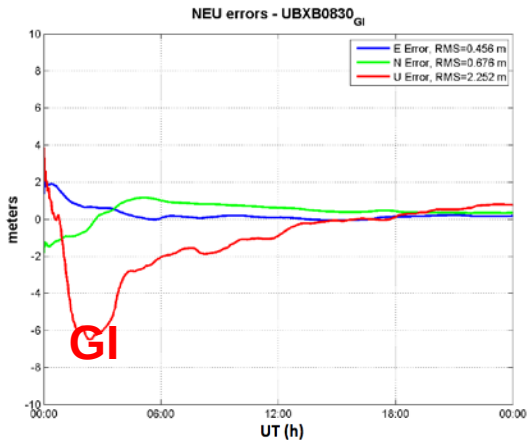


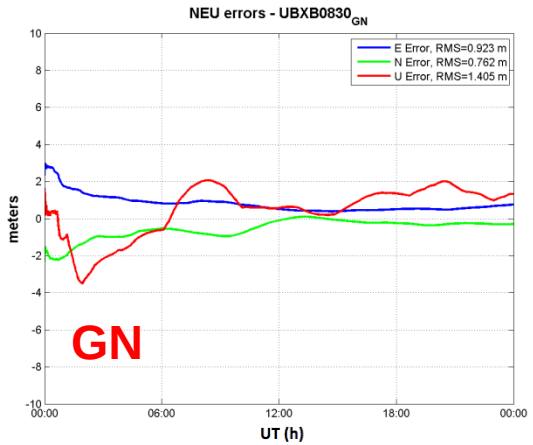


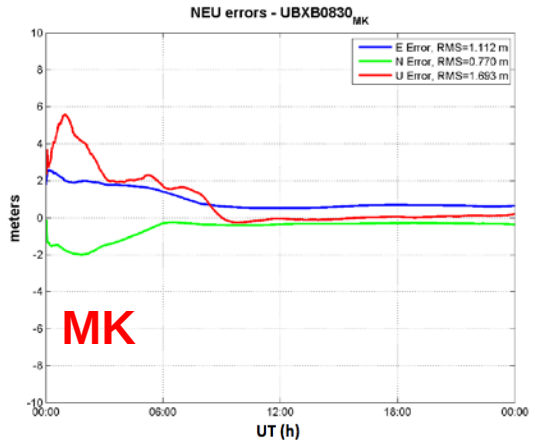
GPS doy 83 – 23th March 2016

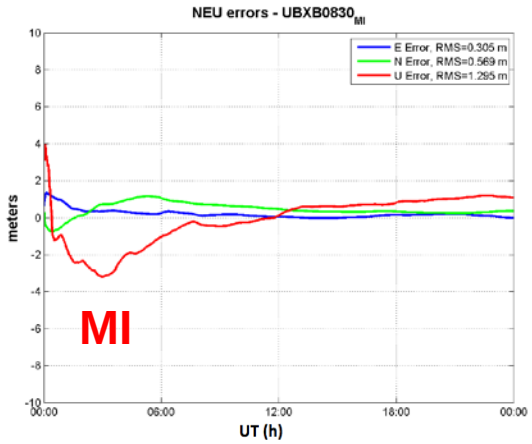
UBXB - Brasilia - session 00:00

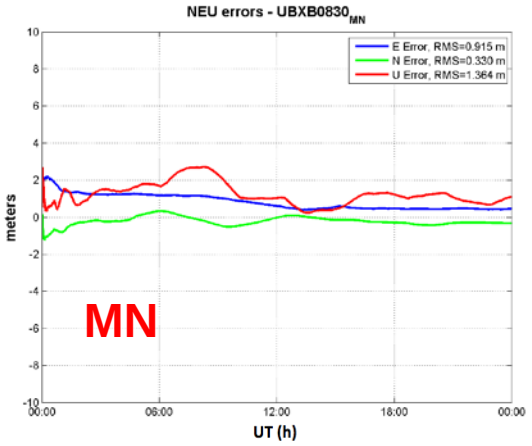






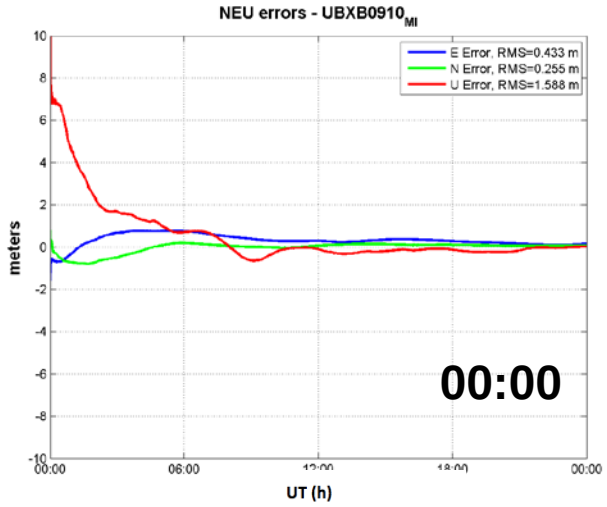


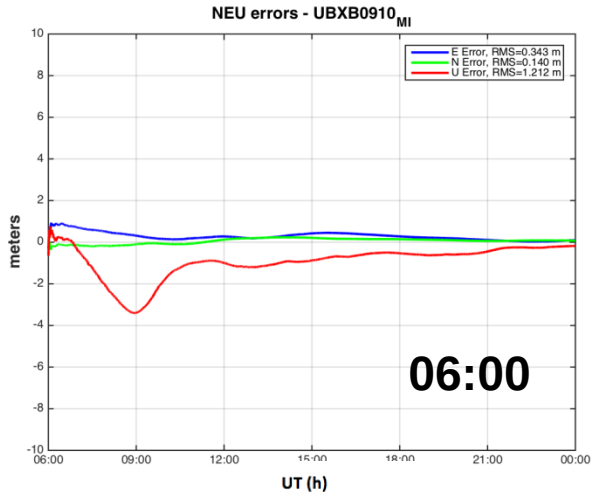


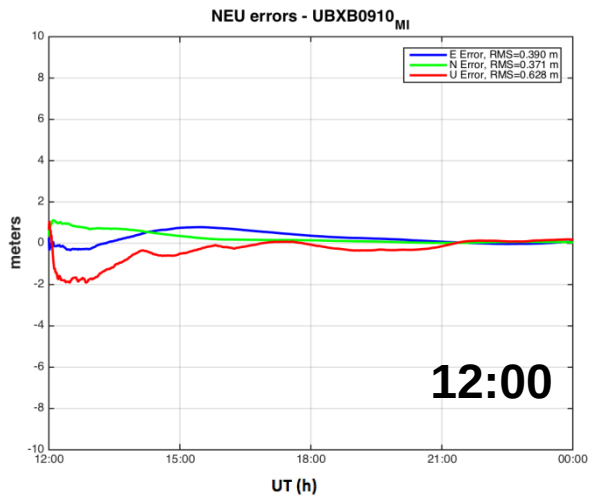


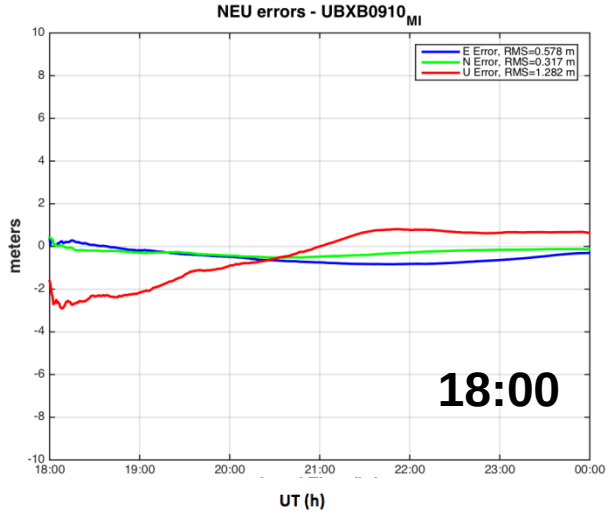
GPS doy 83 – 23th March 2016

Multi constellation – IONEX corr. for different starting time sessions – **UBXB**







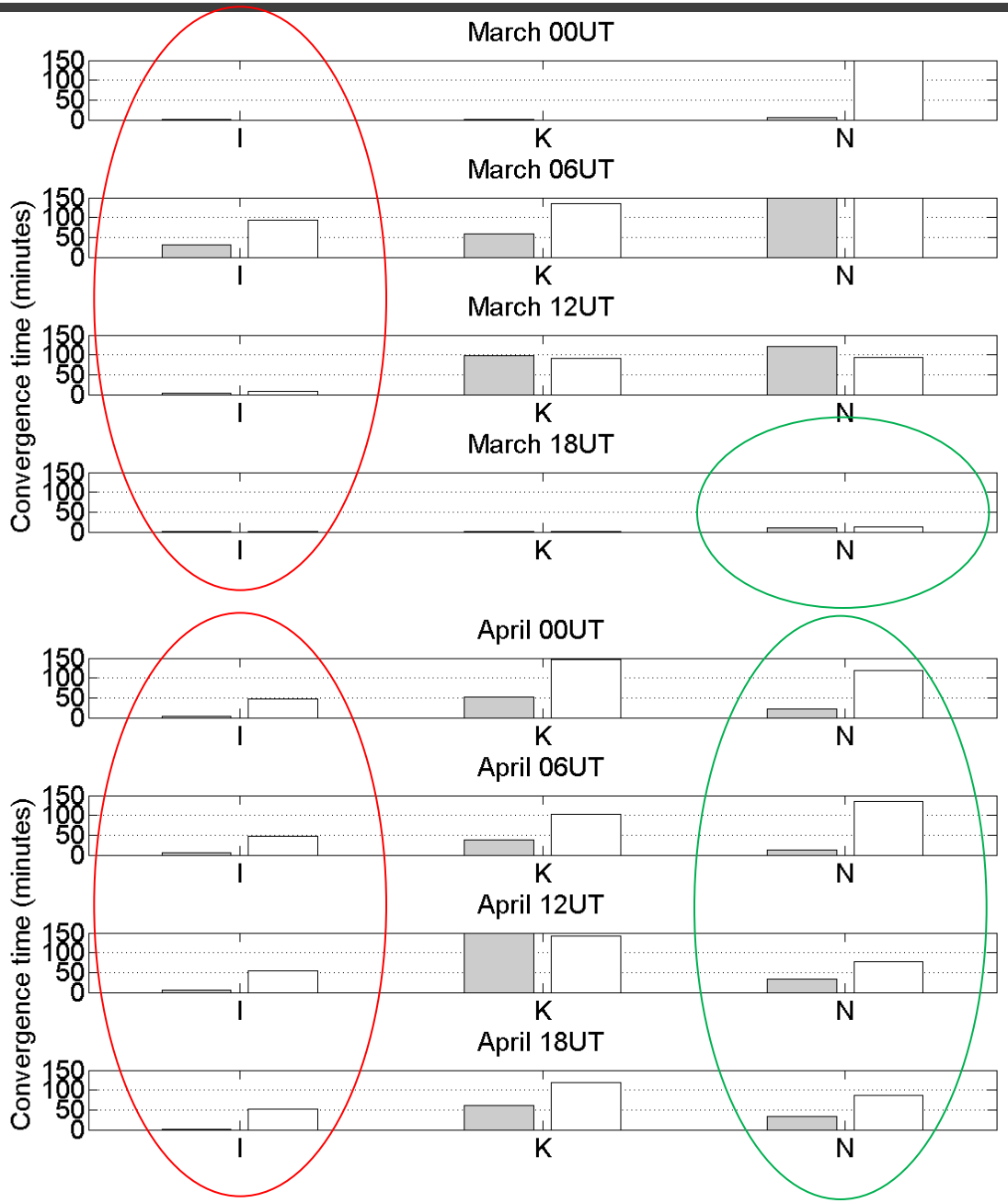


GPS doy 91 – 31st March 2016

Convergence time plots - **UBXT**

March 2016

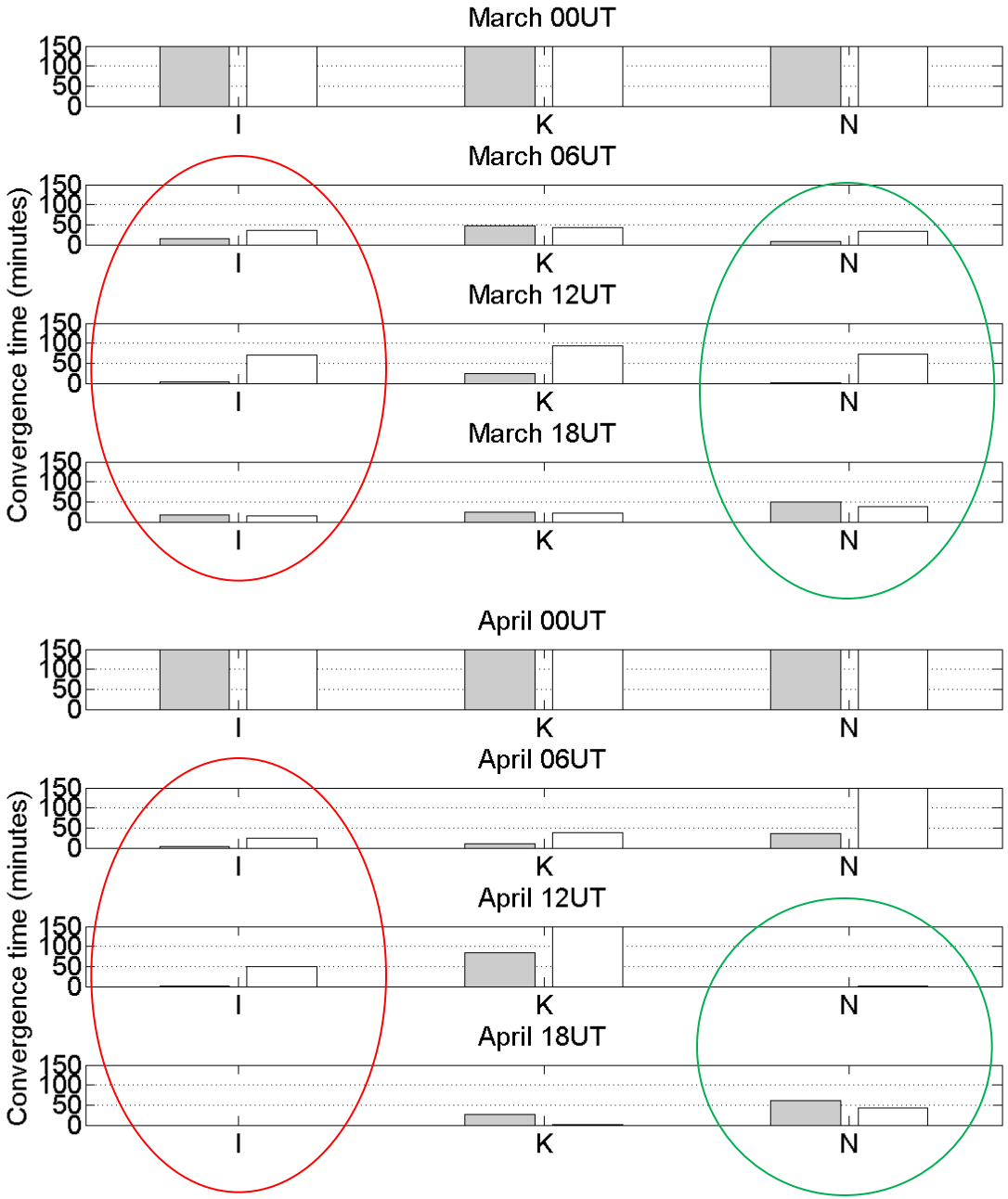
April 2016



Convergence time plots - **UBXB**

March 2016

April 2016



Final remarks

Preliminary considerations

- Preliminary results were obtained from a surveying campaign conducted with mass-market receivers under different ionospheric scenarios.

- This study aims at testing the applicability and accuracy of different ionospheric correction algorithms upon mass-market receiver solutions with the perspective of a future use in real-time kinematic positioning applications.

- The reference coordinates for the u-blox receivers were calculated in post processing mode applying standard differential technique with respect to TRIESTE permanent station TRIE (Regional Network Marussi) and BRASILIA permanent station BRAJ (GLONASS Ground Station Network).

- Considering the first statistical analysis, results confirm that in mid-latitude GIM maps are reliable and outperform the other alternatives.

- NeQuick corrections outperform Klobuchar model particularly in the vertical component (for multiconstellation solution). In the three cases the 3D error slightly decreases when including GLONASS in the PPP solution with a notable improvement in vertical and some degradation in the North direction.

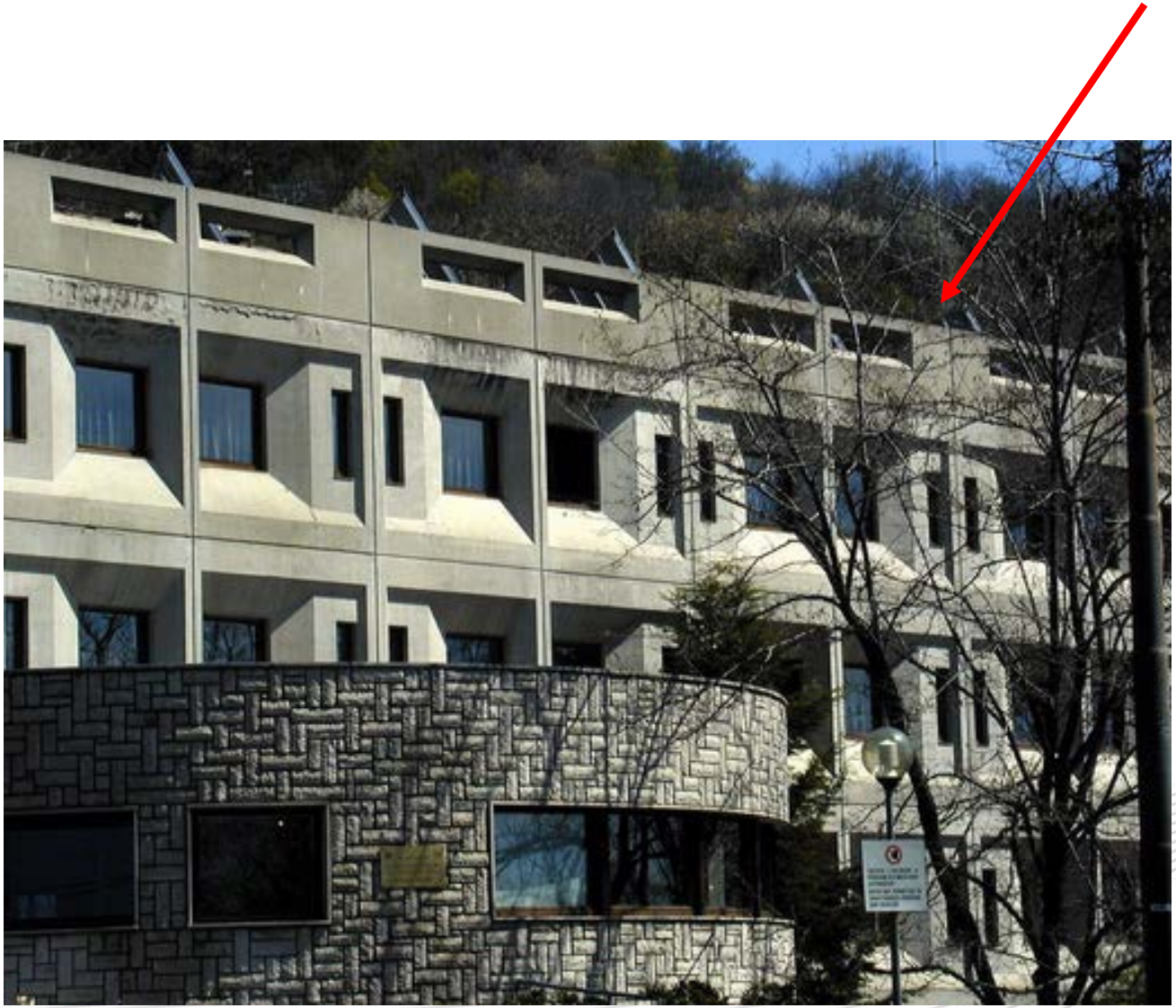
- Especially in the case of UBXB (Brasilia) April accuracy results improve respect to the March ones. This difference is not so remarkable for UBXT (Trieste).

- UBXT (Trieste) results generally show worst performance respect to UBXB. This is not expected at middle latitudes but unfortunatly is due to its location. (“Carso” mountains cover almost half of the sky and also multipath is strongly influencing our measurement). 

- GIM maps solutions show a better performance in terms of convergence time when considering scenarios starting from 6 UT; 12 UT; 18 UT both for UBXT and UBXB and for GPS and multiconstellation solutions.

- NeQuick maps solutions indicate an improvement in terms of convergence time when considering scenarios starting from 12 UT and 18 UT for both month analysed, for both UBXT and UBXB.

GALILEO GUEST HOUSE



References

- Paparini, C.; Borges,R.A ; Villamide, X. O.; Radicella, S. M. A joint project of the University of Brasilia and the International Centre for Theoretical Physics on GNSS applications. In: ICG Experts Meeting on Global Navigation Satellite Systems Services, 2015, Viena. ICG Experts Meeting on GNSS Services - Abstracts, 2015. p. 6-7.
- Van Der Marel, H., De Bakker, P. (2012).GNSS Solutions: Single-versus-Dual Frequency Precise Point Positioning, Inside GNSS.
- https://www.u-blox.com/en, EVK-M8T Manual Evaluation Kit.
- http://www.rtklib.com/
- B. Nava, P. Coïsson, S. M. Radicella, "A new version of the NeQuick ionosphere electron density model", Journal of Atmospheric and Solar-Terrestrial Physics (2008), doi:10.1016/j.jastp.2008.01.01
- ftp://cddis.gsfc.nasa.gov/
- Kashcheyev, A., Nava, B., Migoya Orue', Y. O. and Radicella, S.M. (2015). Real-time ionospheric error correction in single frequency GNSS positioning using NeQuick 2, Proceedings 9thAnnual Baška GNSS Conference, May 10-12, 2015
- http://gnss.regione.fvg.it/dati-GPS/default.jsp
- Moreno, B., Radicella, S.M., Lacy de, M.C., Herraiz, M. (2011). On the effect of the ionospheric disturbances on precise point positioning at equatorial latitudes, GPS Solutions, 15 (4). pp. 381-390. ISSN 1080-5370
- de Paula, E.R., Rodrigues, F.S., Iyer, K.N., Kantor, I.J., et al. (2003). Equatorial Anomaly Effects on GPS Scintillations in Brazil, Advances in Space Research, Volume 31, Issue 3, 2003,doi:10.1016/S0273-1177(03)00048-6


Thank You For Your Attention!


ICTP
U.R.S.I.
EGU European Geosciences Union
NSF
NASA
ICG International Committee on Global Navigation Satellite Systems
AFRL THE AIR FORCE RESEARCH LABORATORY AFOSR
UnB
fapdf Fundação de Apoio à Pesquisa do Distrito Federal
MINISTÉRIO DA CIÊNCIA E TECNOLOGIA AEB AGÊNCIA ESPACIAL BRASILEIRA