The Abdus Salam International Centre for Theoretical Physics

TREGA Project: Towards a SBAS-EGNOS in Sub-Saharan Africa

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ICTP Telecommunication/ICT for Development Laboratory

Training on EGNOS-GNSS in Africa (TREGA)

Contents

- TREGA project: training through research
- Ionosphere features over Africa
- Sub-Saharan Africa scenario
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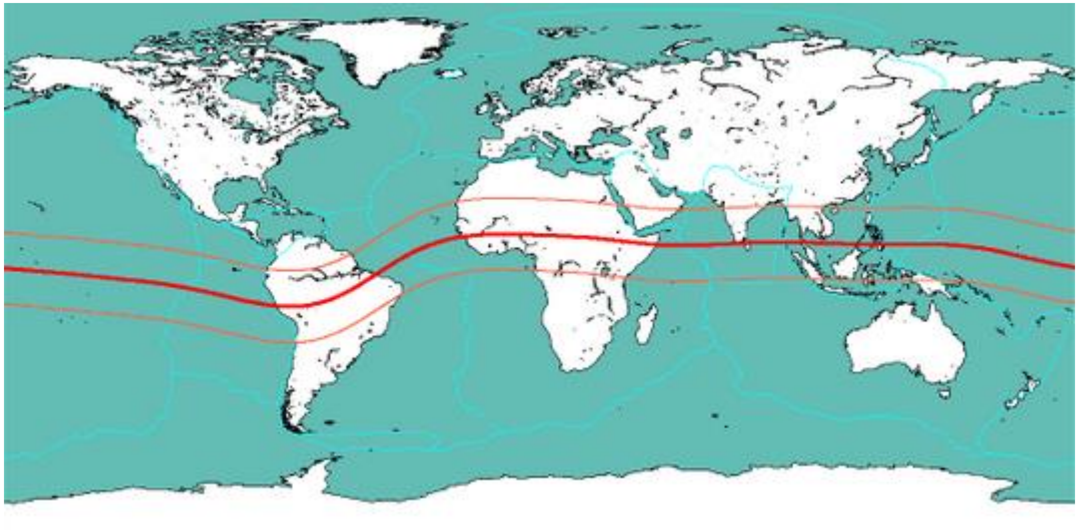
TREGA training through research

- TREGA: “**Training through** research”on EGNOS-GNSS in Africa (EC-ICTP) is being carried out in the TREGA LABORATORY.
- Scenario of a possible SBAS configuration in West Sub-Saharan African region using real data during solstice and equinox months of 2013, characterized by high solar activity.
- Outputs: Analysis of SBAS system performance and ionospheric conditions.
- Laboratory Platform: **magicSBAS**. PS SBAS emulator with a specific low-latitude algorithm.

Ionosphere features over Sub-Saharan Africa (I)

- Sub-Saharan Africa lies within the Ionospheric Equatorial Anomaly (IEA).
- 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.



Ionosphere features over Sub-Saharan Africa (II)

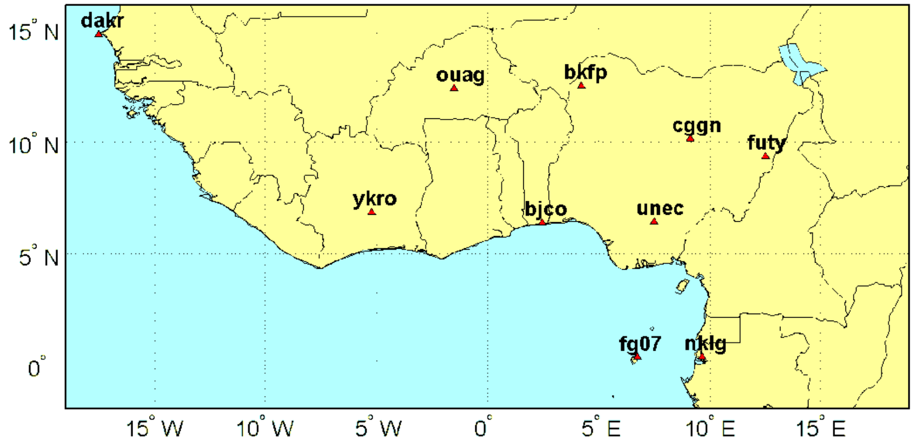
- IEA shows very large diurnal, day-to-day and seasonal variations
- It is characterized by the presence of severe ionospheric irregularities after sunset
- It is influenced by solar and geomagnetic activity
- The **IEA development** maximizes during equinoxes and it is lower during solstice months
- Different **parameters** can be used to study Ionosphere variability and its causes:
  - Total Electron Content (TEC) and TEC Rate of Change / Rate of Change Index: (ROT / ROTI)
  - geomagnetic indices: Kp, Dst, ap
  - solar parameters: solar wind speed, IMF, Bz

Ionosphere features over Sub-Saharan Africa (III)

Low-latitude ionosphere is more complex than mid-latitude ionosphere:

- It causes more delay on L band frequency (GNSS) because of the high values of (TEC).
- The irregularities produce large fluctuations in L band signals (high TEC rate of change and scintillations).

TREGA scenario



Spatial & Temporal

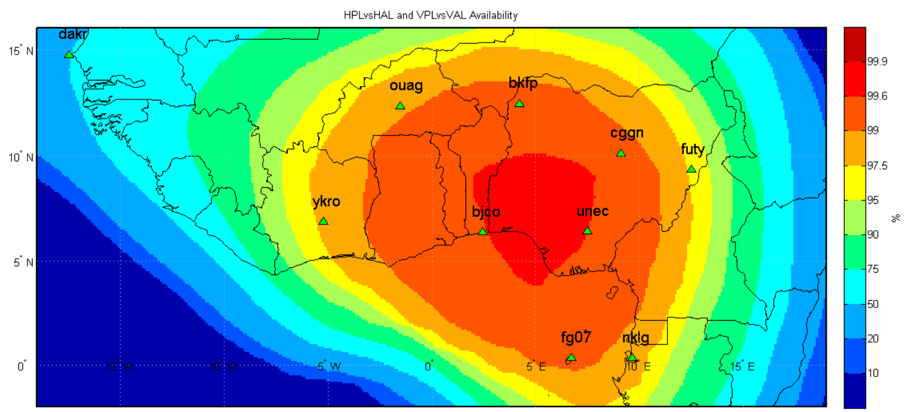
data availability

ID	Location	Network	Geo. Lat (ºN)	Geo. Lon (ºE)	Modip (º)
cggn	Toro (Nigeria)	NIGNET	10.12	9.12	-1.96
ouag	Ouagadougou (Burkina Faso)	AFREF/ IGS	12.35	-1.51	2.86
futy	Yola (Nigeria)	NIGNET	9.35	12.50	-3.34
bkfp	Kebbi (Nigeria)	NIGNET	12.47	4.23	3.50
ykro	Yamoussoukro (Cote d'Ivorie)	AFREF/ IGS	6.87	-5.24	-10.63
unec	Enugu (Nigeria)	NIGNET	6.42	7.51	-10.89
bjco	Cotonou (Benin)	AFREF/ IGS	6.23	2.27	-11.83
dakr	Dakar (Senegal)	AFREF/ IGS	14.75	-17.49	11.86
nklg	Libreville (Gabon)	AFREF/ IGS	0.35	9.67	-23.90
fg07	Sao-Tome (Soa-Tome)	SONEL	0.34	6.73	-24.60

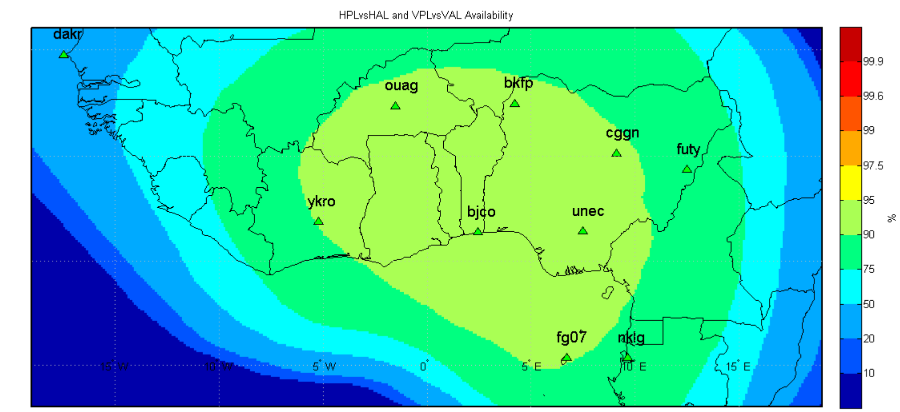
•AFREF Network - GPS data: http://www.afrefdata.org/
•NIGNET Network – GPS data: www.nignet.net-NIGNET
•SONEL Network - GPS data: http://www.sonel.org/-GPS-.html?lang=en

APV-1 monthly availability low-latitude algorithm

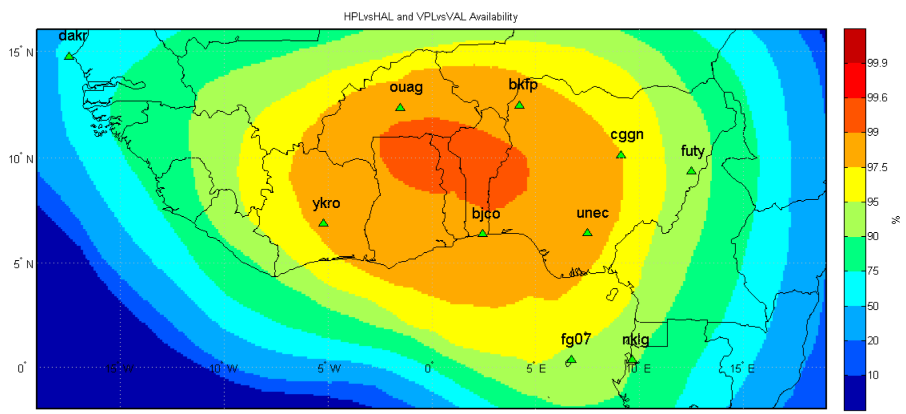
JANUARY 2013



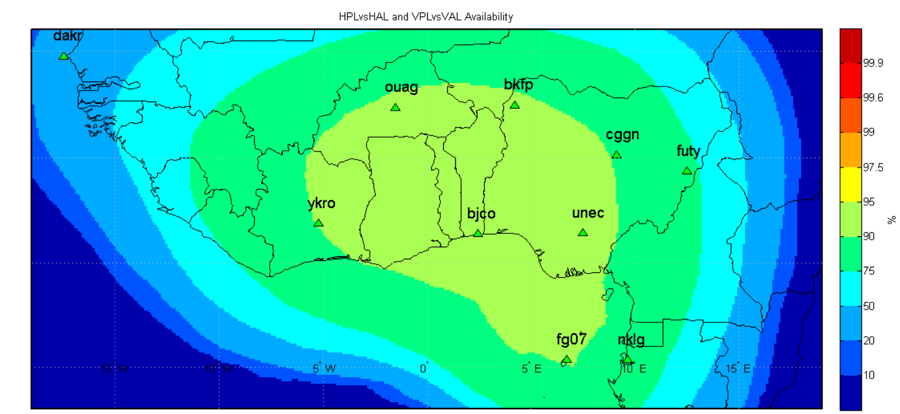
APRIL 2013



JULY 2013

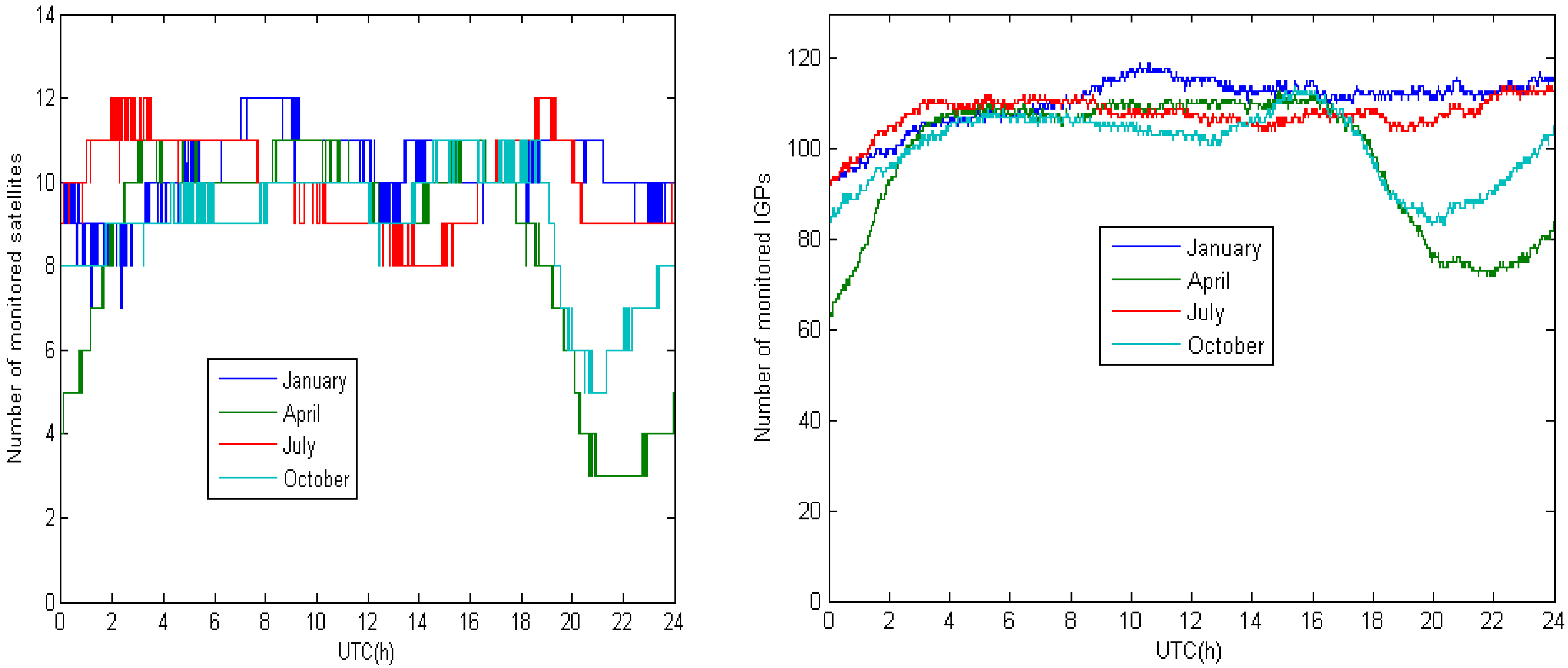


OCTOBER 2013



Baska GNSS Conference 2015, Croatia, [ref 1]

Analysis of monitored PRNs and IGPs



Decrease in number of monitored PRNs and IGP after sunset during equinoctial months

Baska GNSS Conference 2015, Croatia, [ref 1]

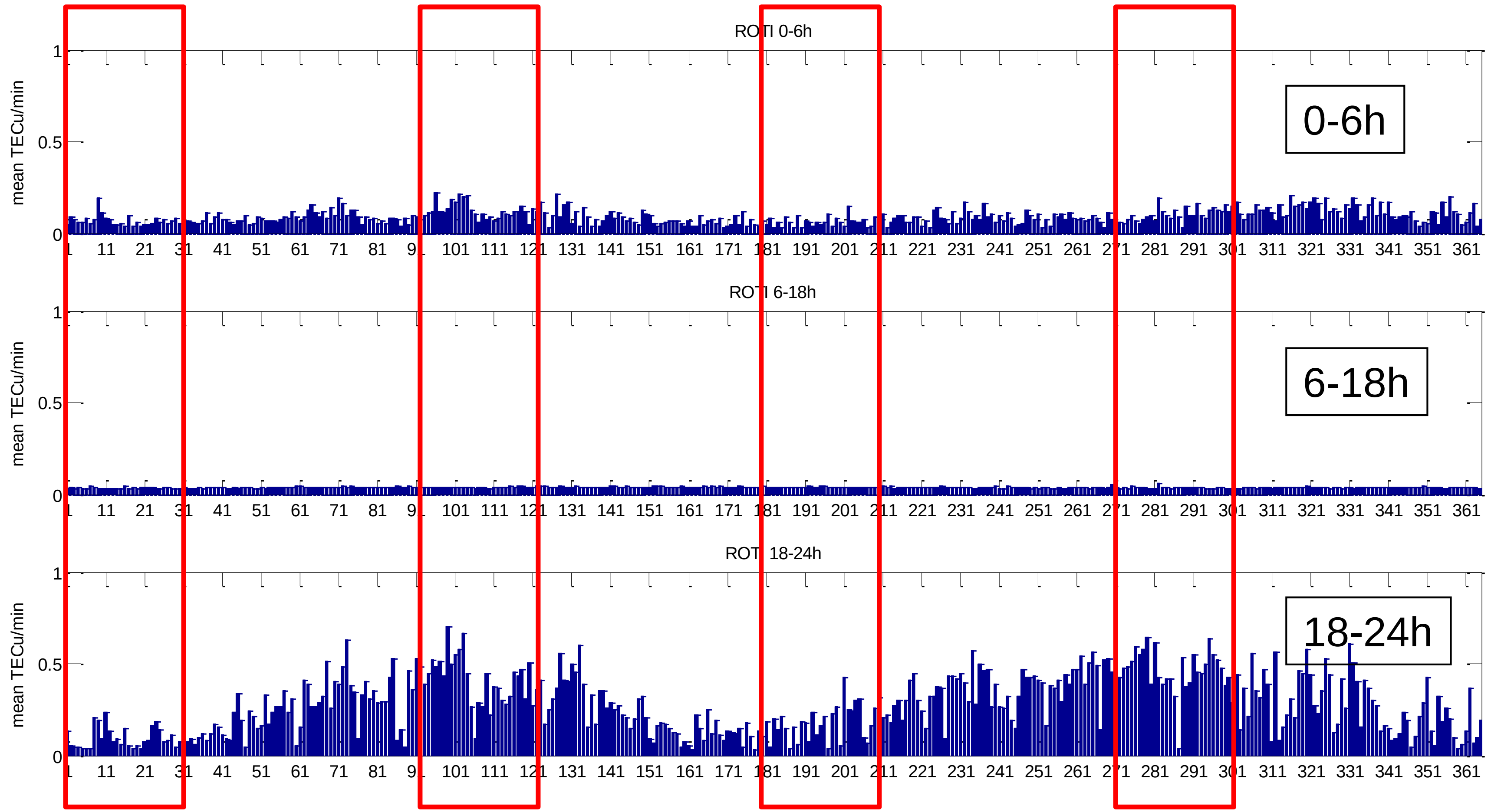
Rate of Change of TEC (ROT) / Index (ROTI)

- **Rate of change of TEC (ROT)** is the time derivative of TEC that measure ionospheric irregularities.

- **Rate of change of TEC Index (ROTI)** is defined as GPS based index that characterizes the severity of the fluctuations, detects the presence of ionospheric irregularities and irregular structure of TEC spatial gradients.

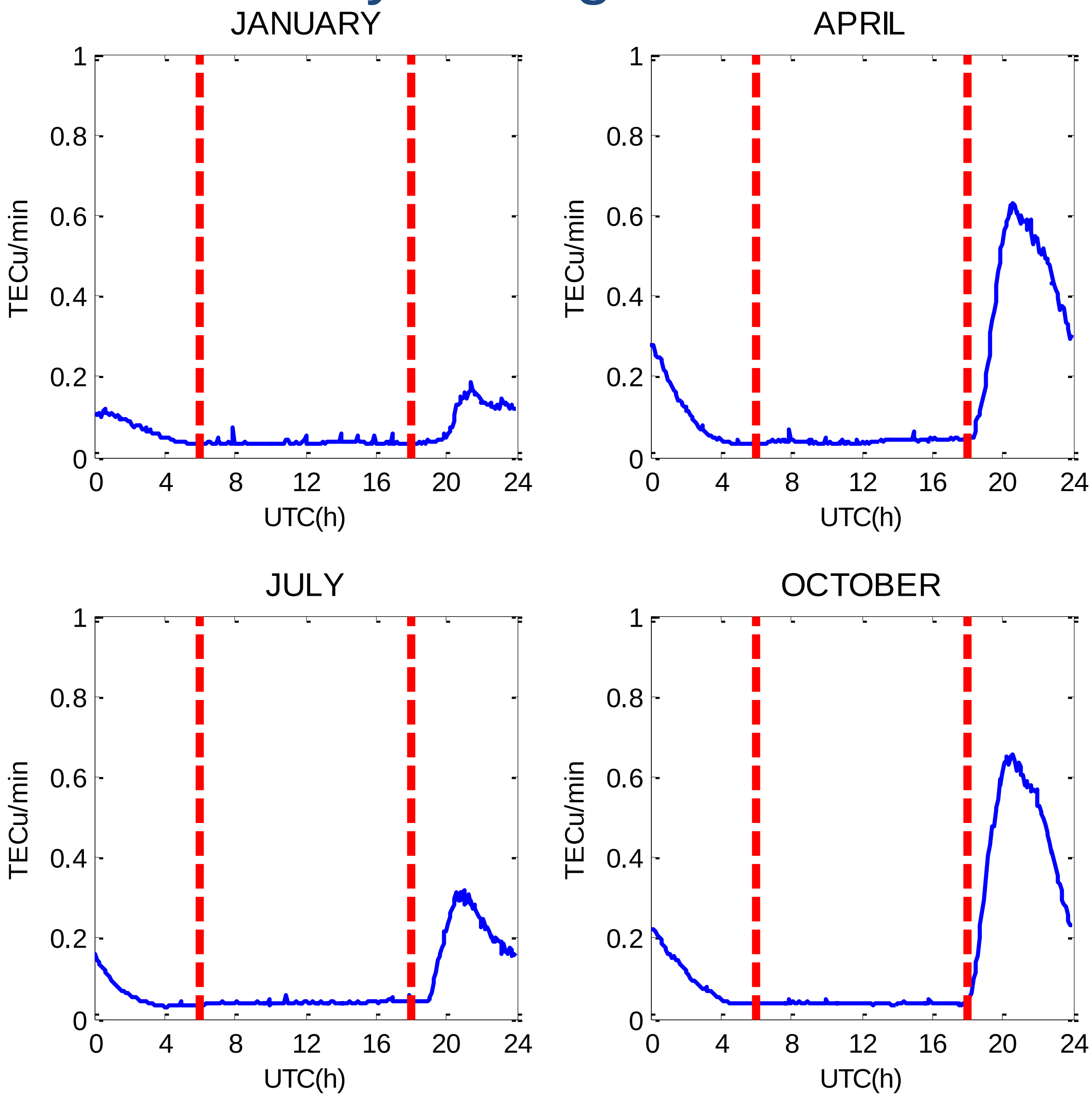
  It can be obtained by taken the standard deviation of ROT at every 5 minutes interval.

Yearly evolution of ROTI for 2013



European Navigation Conference 2015, Bordeaux, France, [ref 2]

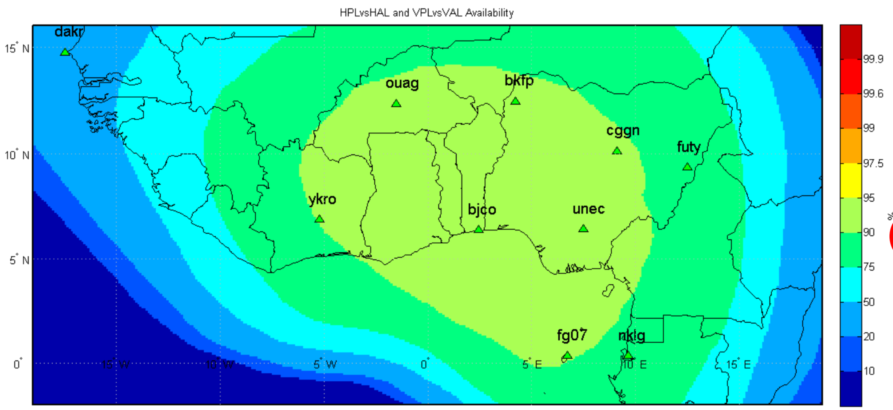
Analysis of monthly averaged ROTI



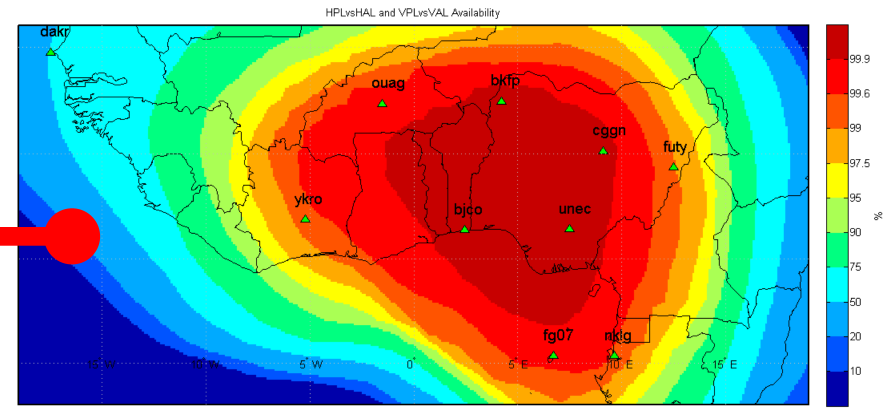
European Navigation Conference 2015, Bordeaux, France, [ref 2]

Availability for Equinoxes 2013 / low-latitude algortithm

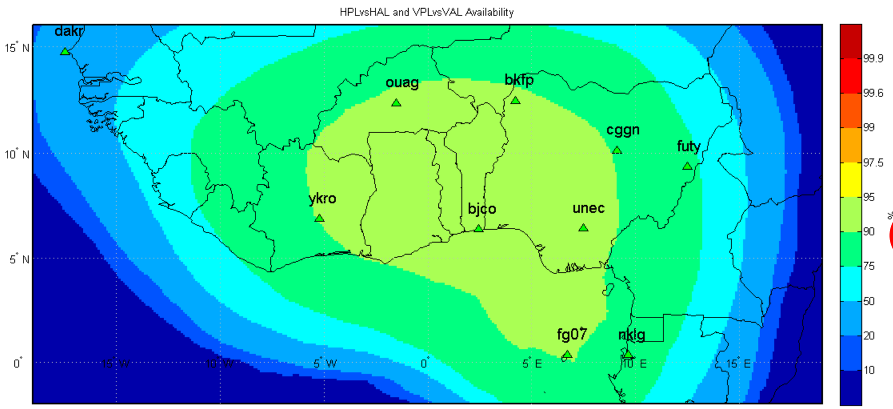
APRIL 24h



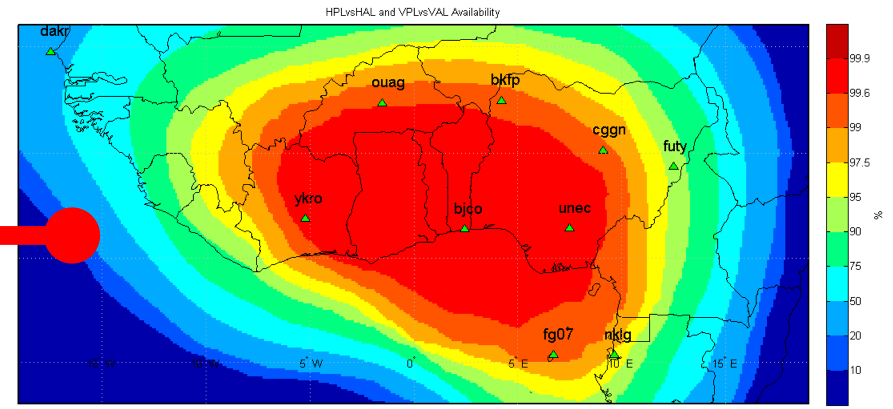
APRIL **4h-18h**



OCTOBER 24h

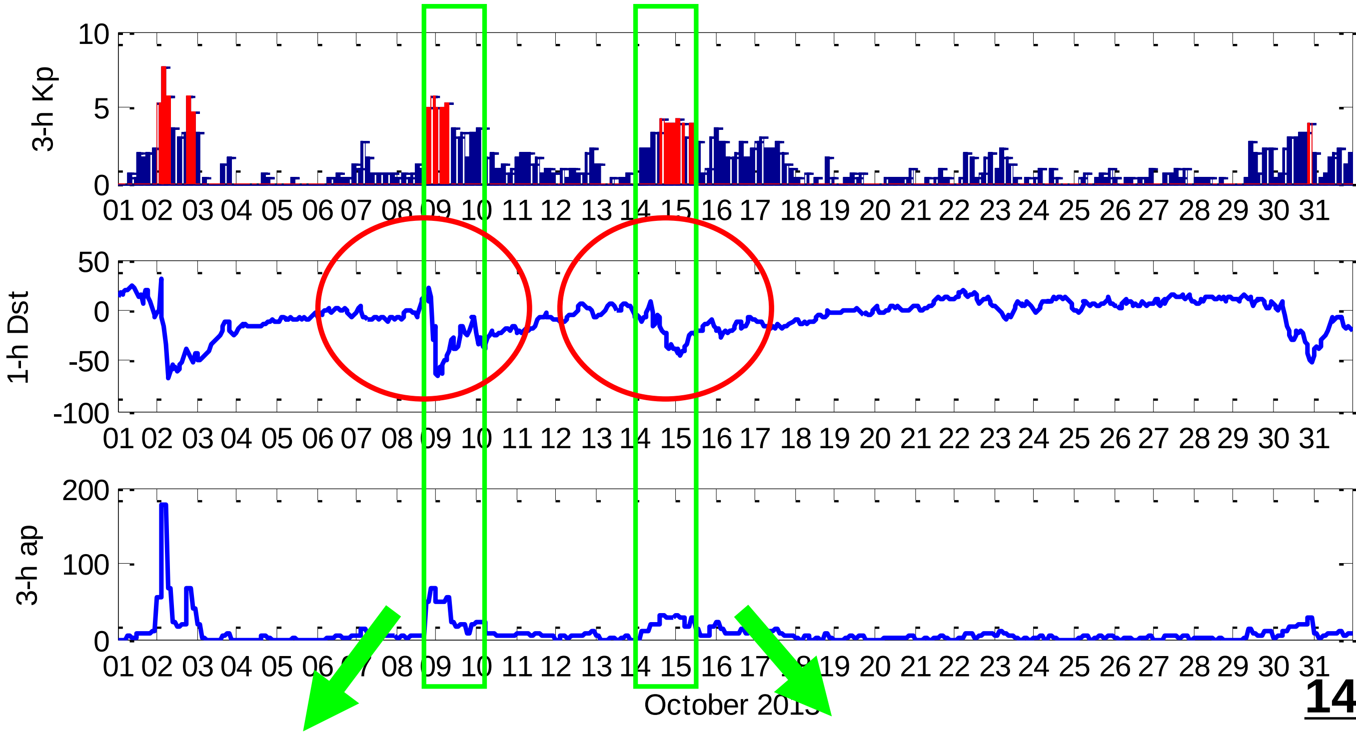


OCTOBER **4h-18h**



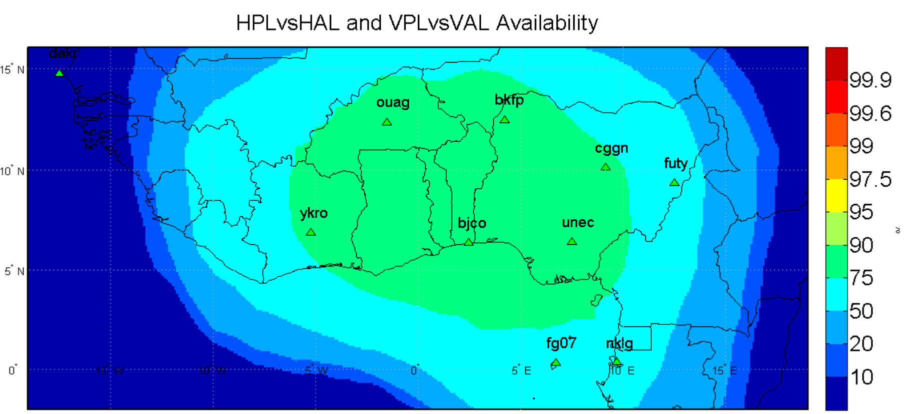
Baska GNSS Conference 2015, Croatia, [ref 1]

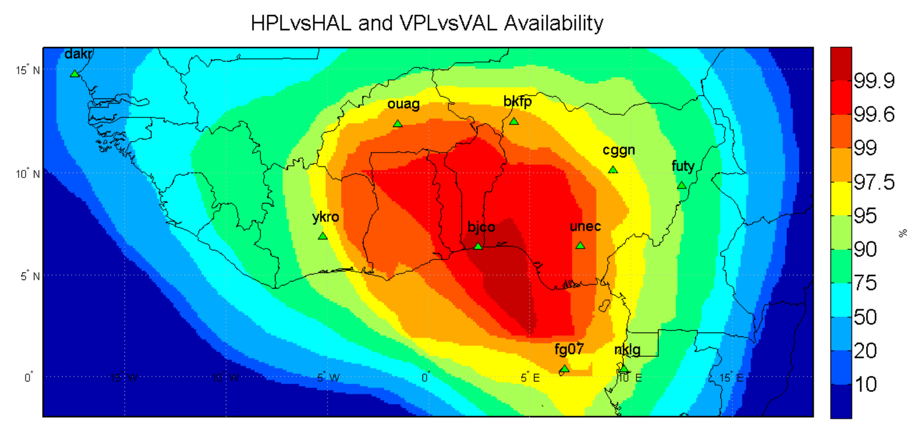
Storm-Time Assessment of GNSS-SBAS Performance



9th October

14th October

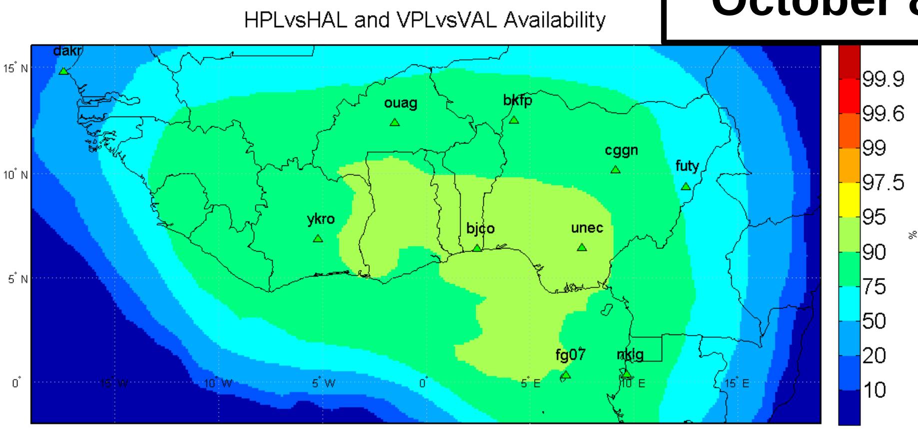




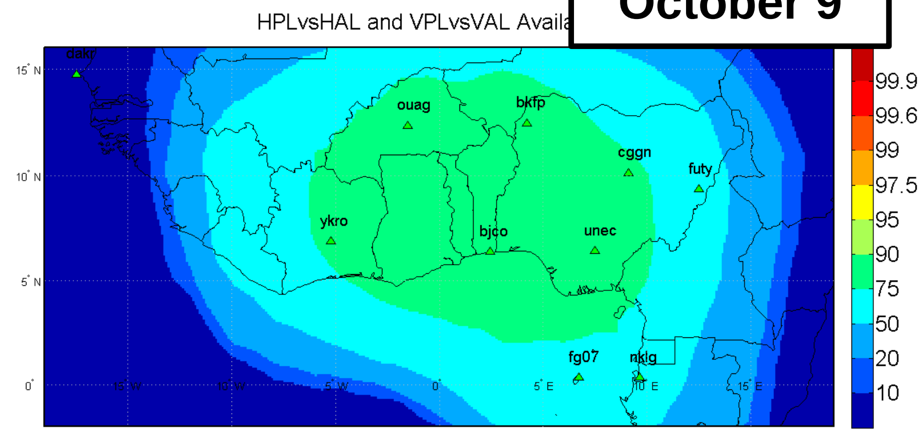
European Navigation Conference 2015, Bordeaux, France, [ref 2]

APV-1 availability maps indicating degradation in SBAS performance for October 9th

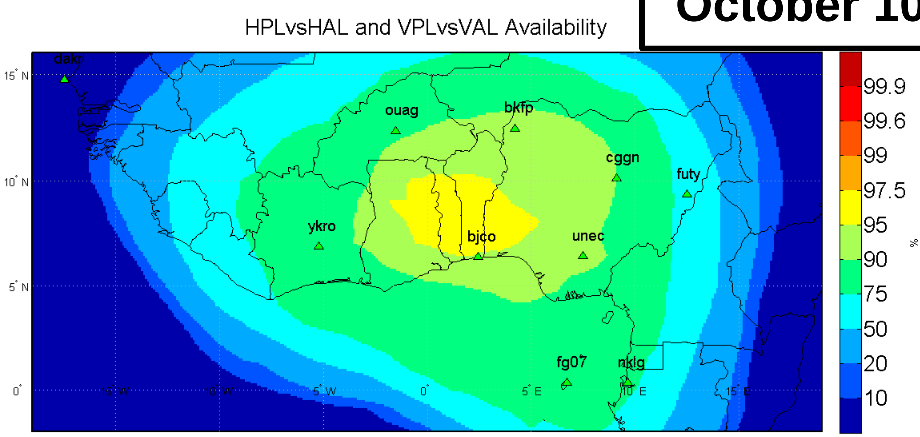
October 8



October 9



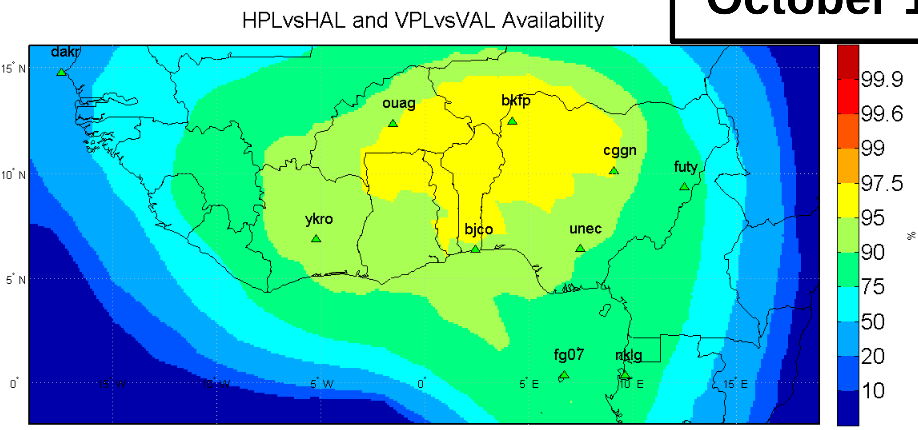
October 10



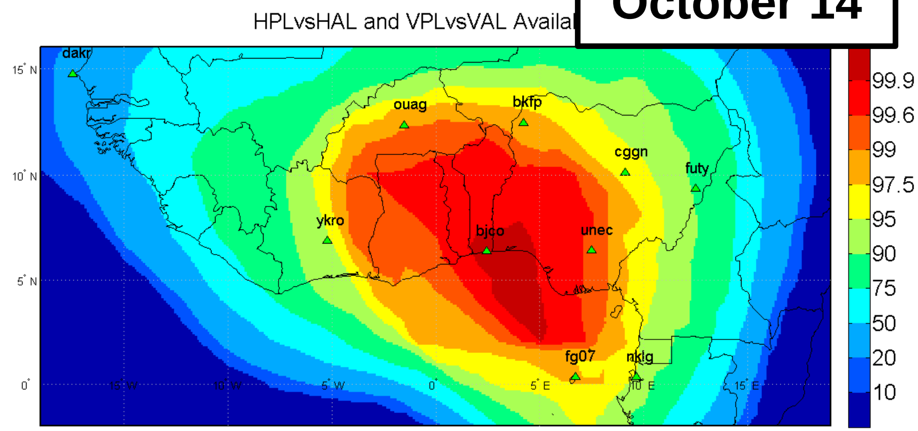
IES 2015 [ref 3]

APV-1 availability maps indicating enhancement in SBAS performance for October 14th

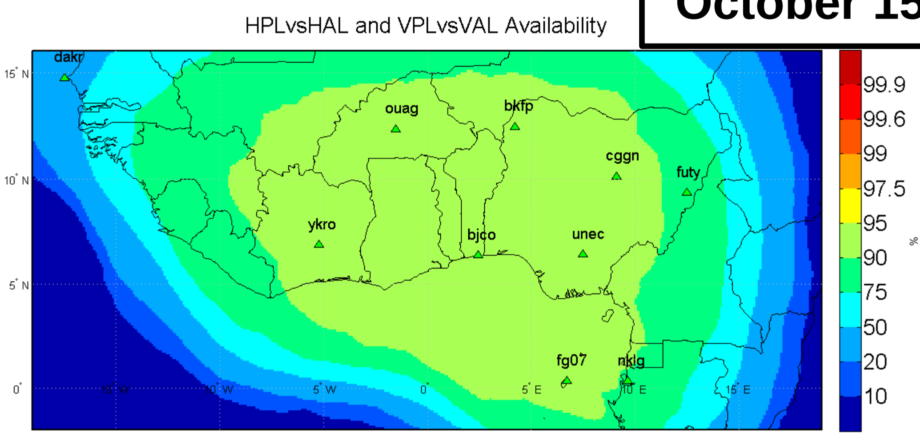
October 13



October 14

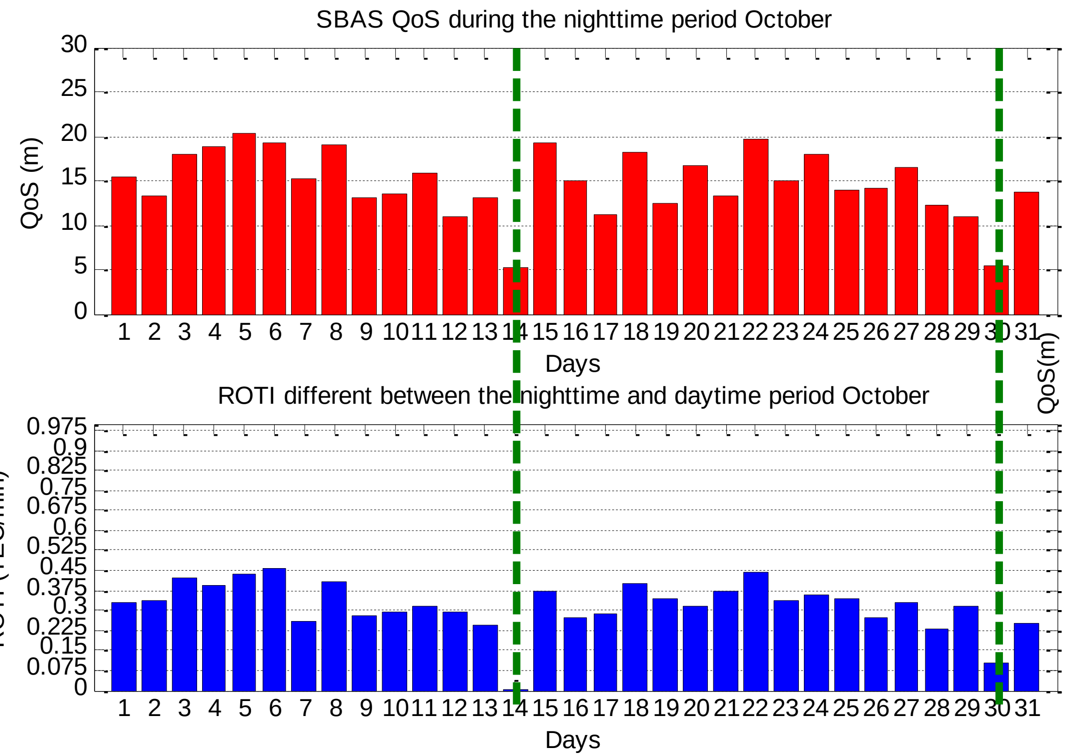


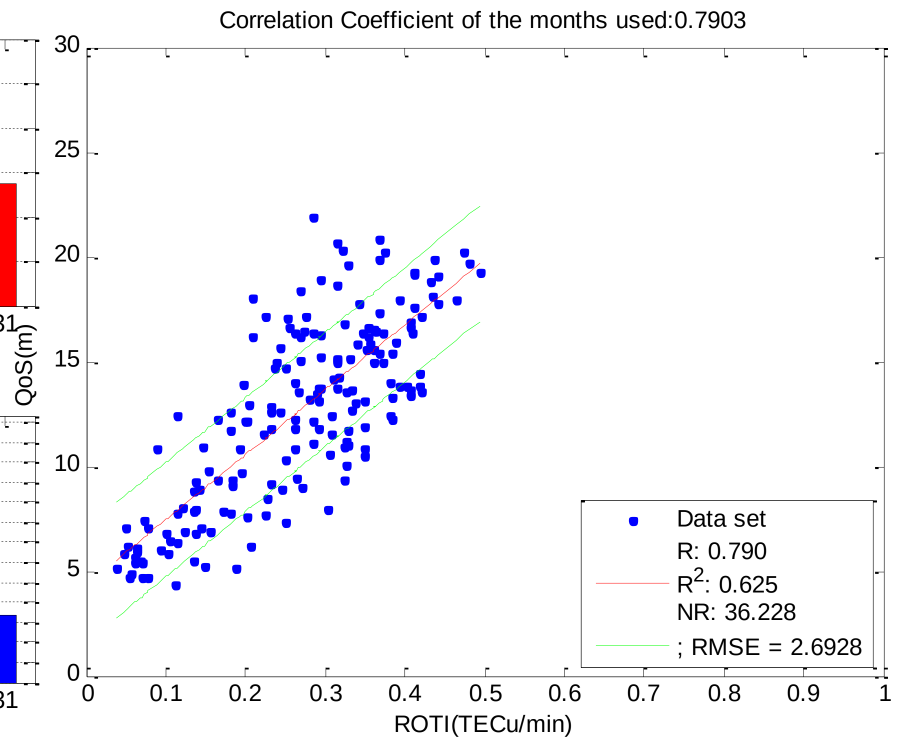
October 15



IES 2015 [ref 3]

Correspondence between ionospheric plasma irregularities and SBAS quality of service





URSI 2015, ISEA 2015 [ref 4 - 5]

Summary

- ROTI has been proved as a good proxy for the presence of ionospheric irregularities and a representative parameter of the SBAS performance.
- The presence of ionospheric irregularities can explain in a great portion the degradation of the SBAS system performance after sunset hours.
- It is expected that the use of a ground segment in Sub-Saharan Africa dedicated for SBAS purposes (i.e. better spatial distribution and quality of observables) would improve the results obtained.

TREGA references

1. H. Ngaya, C. Paparini, O.E. Abe, X. Otero Villamide, S.M Radicella, B. Nava, "Possibility of SBAS usage in Sub-Saharan African Regions", Baska GNSS Conference, 10-12 May 2015, Baska, Croatia.
2. C. Paparini, H. Ngaya, O.E. Abe, X. Otero Villamide, S.M Radicella, B. Nava, "SBAS Navigation Performance Evaluation in Sub-Saharan Africa", European Navigation Conference , Bordeaux, France, April 8th 2015.
3. O.E. Abe, C.Paparini, H.Ngaya, X.Otero, S.Radicella, B.Nava "The storm-Time Assessment of GNSS-SBAS Performance within African Equatorial and Low Latitude Region", 14th International Ionospheric Effects Symposium, IES, May 12th-14th 2015.
4. X. Otero, O.E. Abe, C. Paparini, H. Ngaya, S. Radicella, B. Nava, "Effect of Equatorial and Low Latitude Ionospheric Irregularities on SBAS", URSI AT-RASC 2015, Gran Canaria, Canary Islands, 18-25 May, 2015.
5. O.E.Abe, X. Otero Villamide, C. Paparini, H. Ngaya, S.M. Radicella, B.Nava. "Signature of Ionospheric Irregularities under different geophysical conditions on SBAS System Performance in the West Low-Latitude Region", International Symposium on Equatorial Aeronomy (ISEA), Bahir Dar, Ethiopia, October 19th-23rd 2015.

Thank you for your attention