The Abdus Salam International Centre for Theoretical Physics
50th Anniversary

Training on EGNOS-GNSS in Africa (TREGA)

The Abdus Salam International Centre for Theoretical Physics
A project implemented by ICTP

Funded by the European Union

X. Otero, C. Paparini, O.E. Abe, H.R. Ngaya, S. M. Radicella, B. Nava

UN / ICTP

Contents

- Definition of Sub-Saharan African scenario
- Analysis of SBAS performance
- Ionospheric effects on SBAS performance
- User case example
- Conclusions

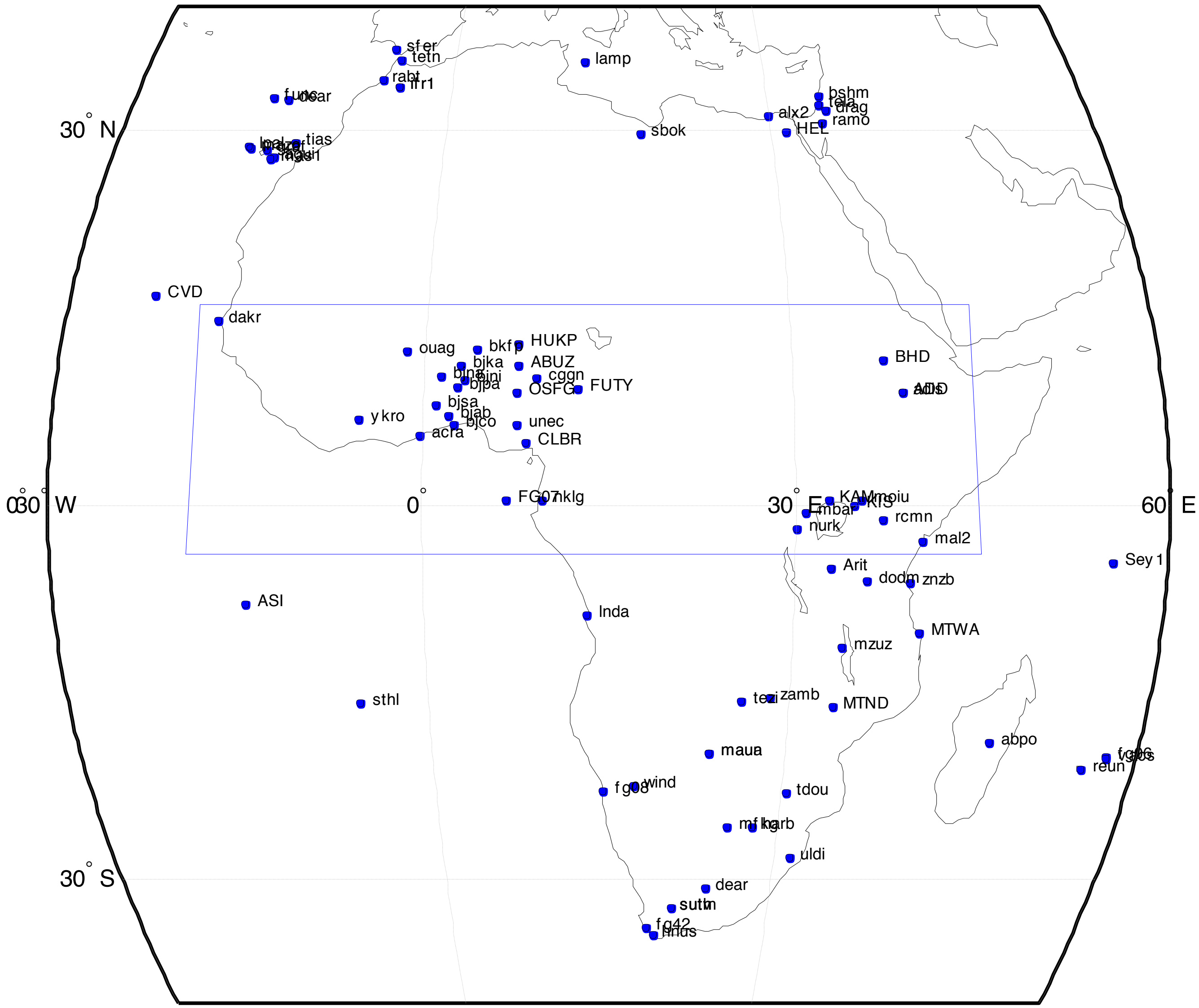
TREGA training through research

- **Main goal:** Study a potential SBAS performance in the Sub-Saharan African region

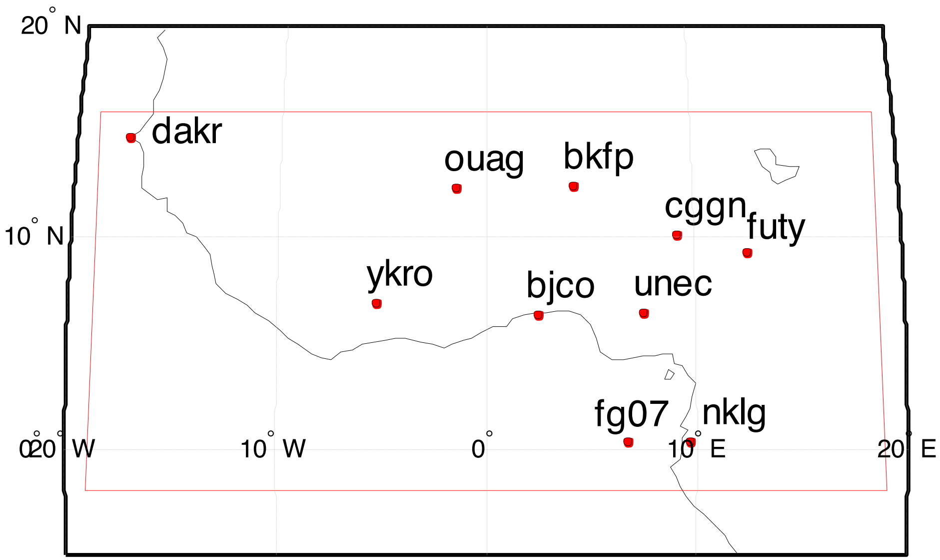
- **Scenarios** of a SBAS system in Sub-Saharan Africa using **real data** during **solstice** and **equinox** months of **2013**, characterized by high solar activity

- Analysis of **SBAS system and user level performance** and **ionospheric conditions** of the defined scenarios

Overview of GNSS stations in Africa

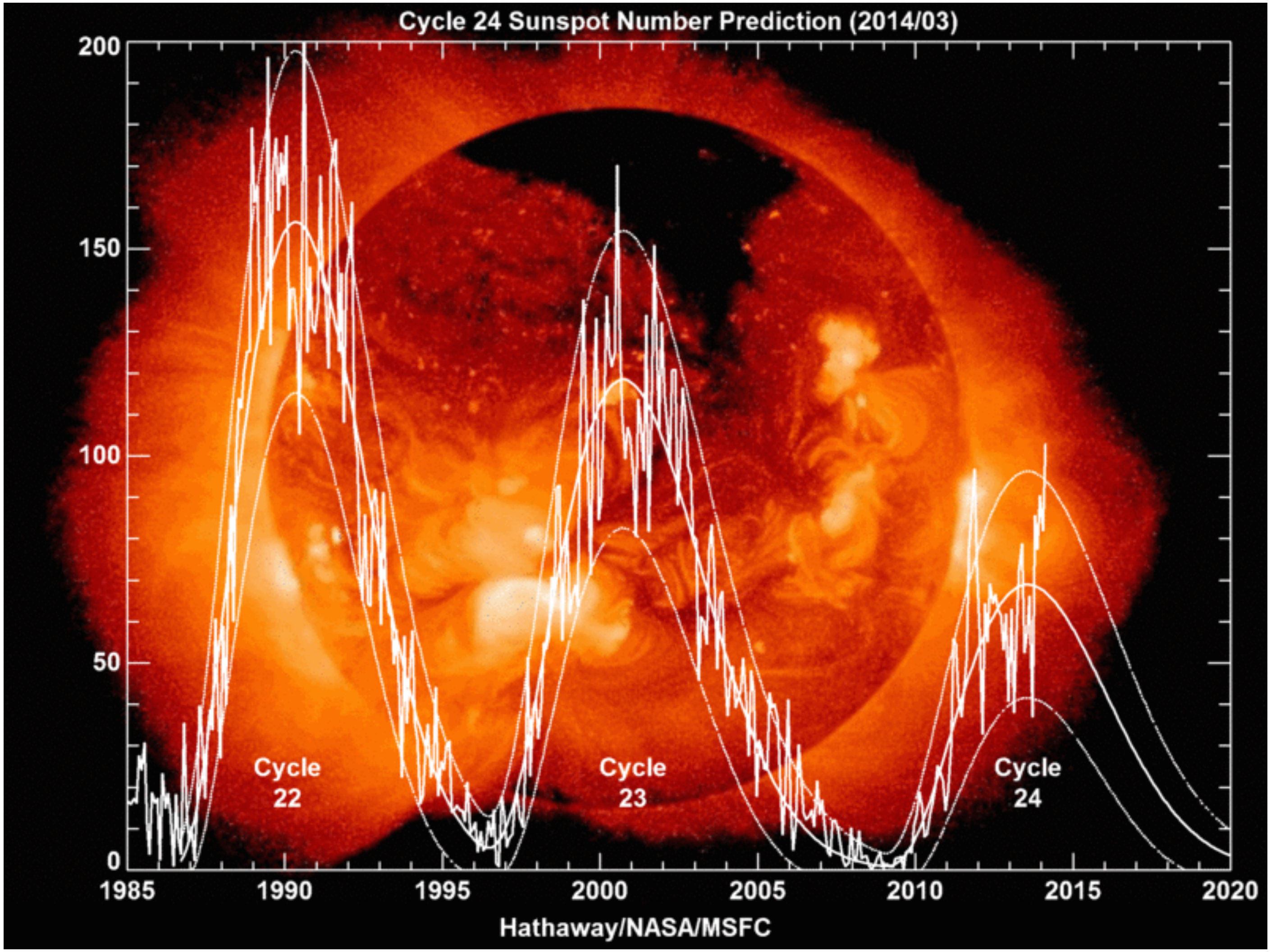


TREGA scenario



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

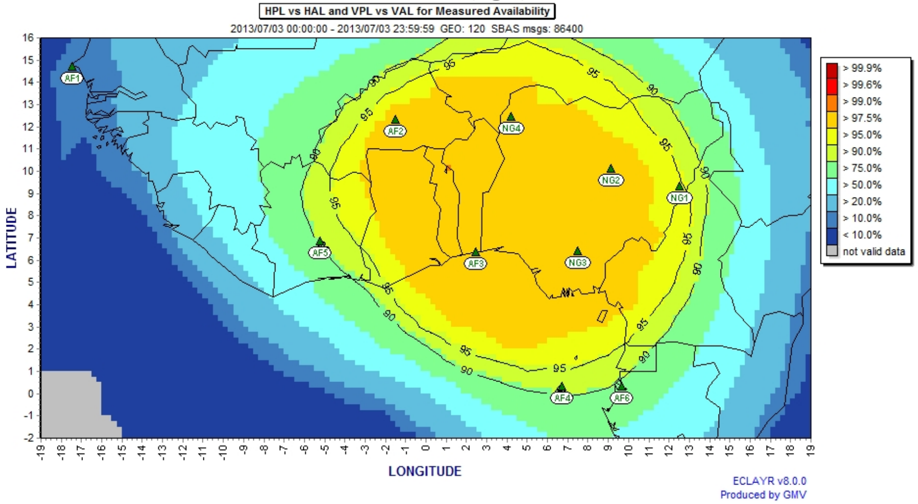
Cycle 24 Sunspot Number



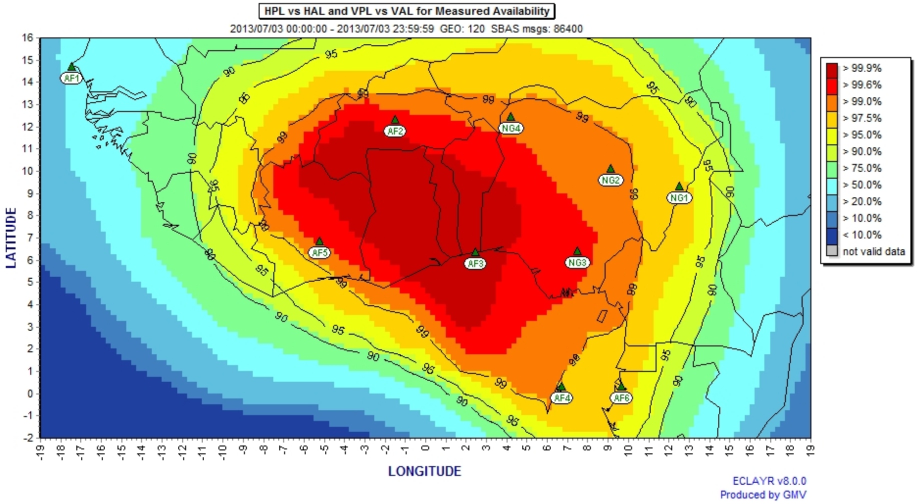
http://solarscience.msfc.nasa.gov/SunspotCycle.shtml

APV-I performance for July 2013 24h

EGNOS-like Processing Set v. 2.3.2



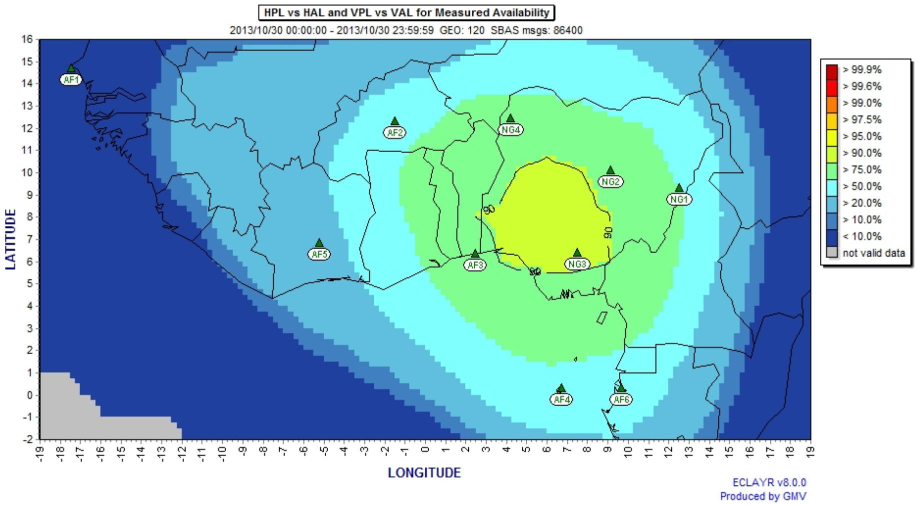
Low-latitude algorithm



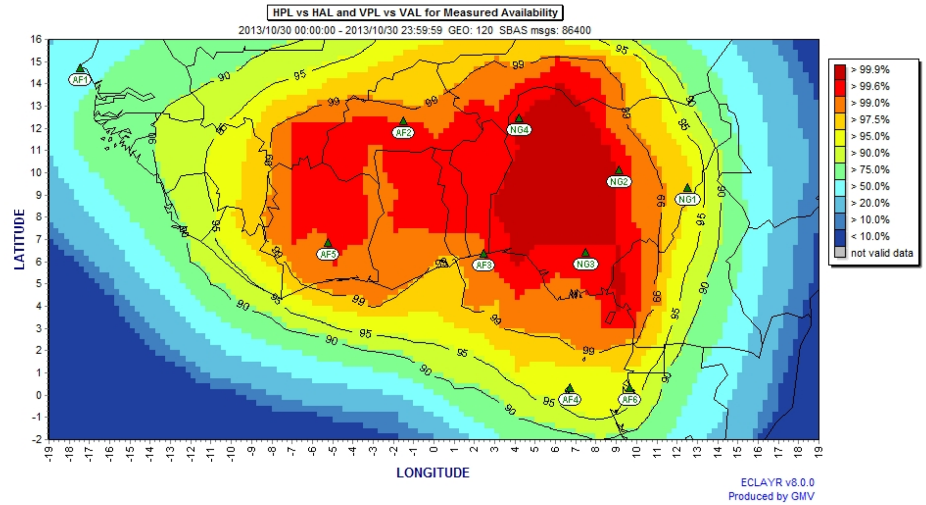
03-07-2013

APV-I performance for October 2013 24h

EGNOS-like Processing Set v.



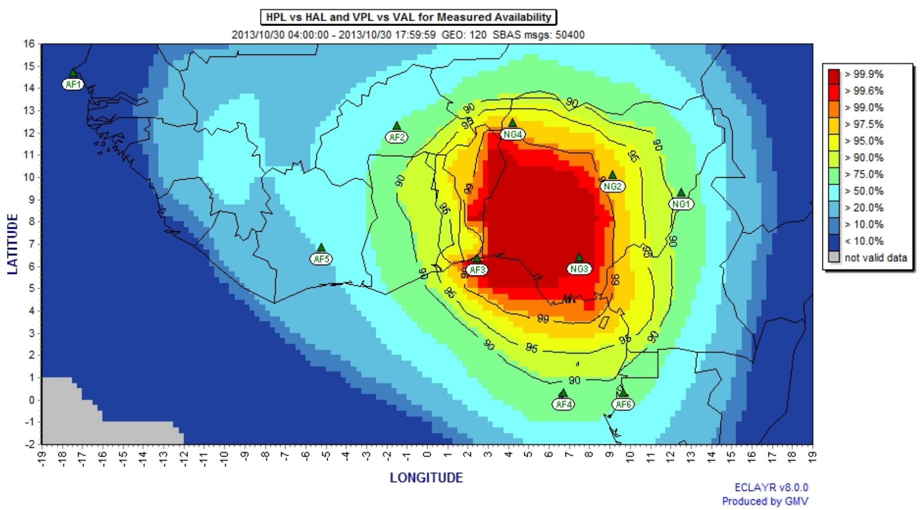
Low-latitude algorithm



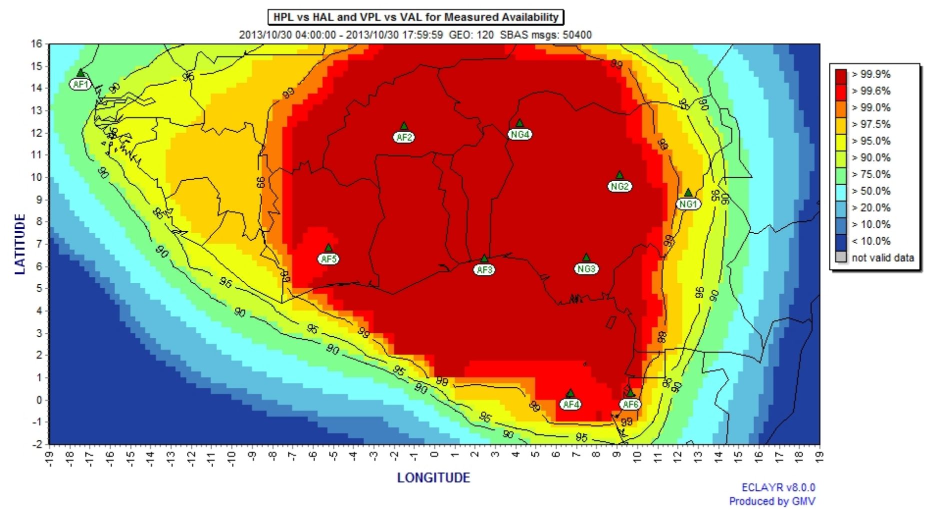
30-10-2013

APV-I performance for October 2013 14h (4:00 – 18:00 UTC)

EGNOS-like Processing Set v.



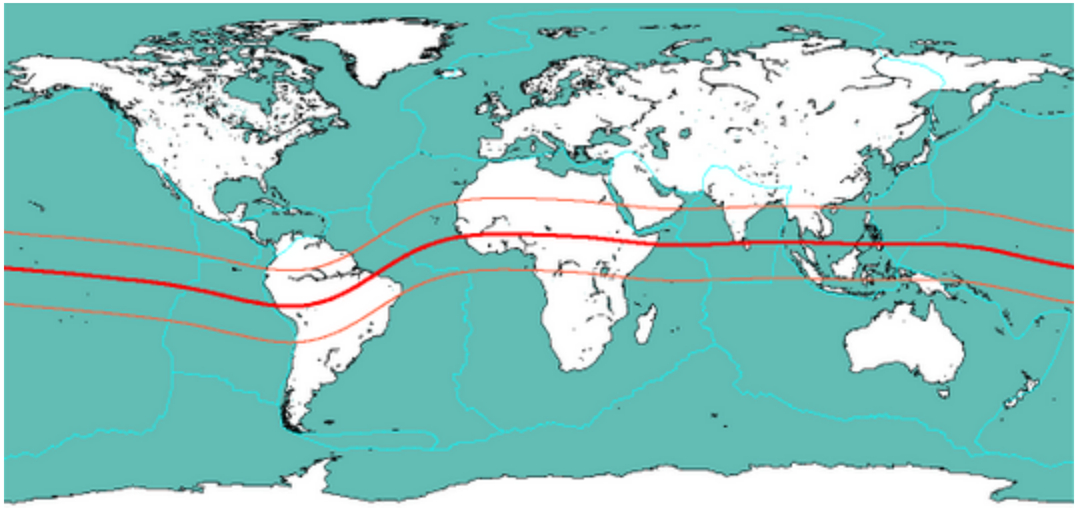
Low-latitude algorithm



30-10-2013

Study of Ionospheric Effects
Features of Ionosphere over Africa (I)

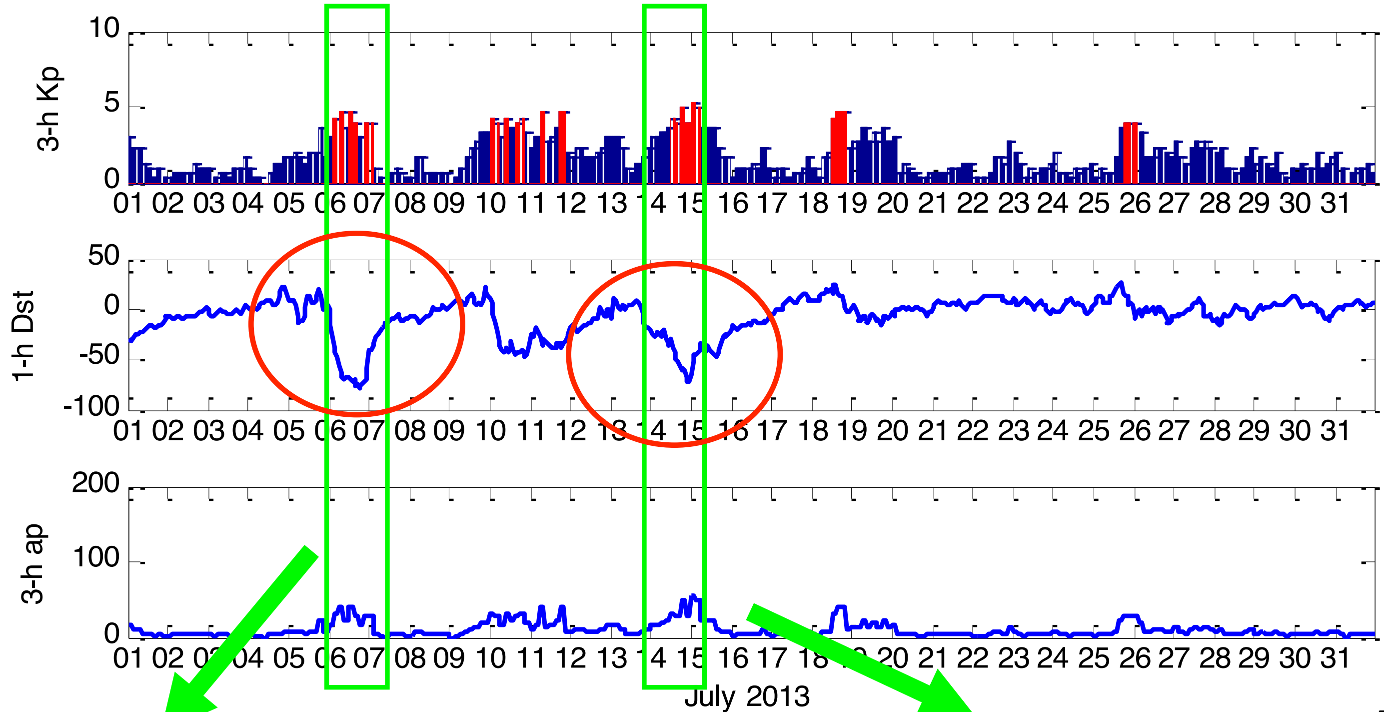
- Sub-Saharan Africa lies under the Ionospheric Equatorial Anomaly (IEA)
- The IEA is characterized by two crests of electron density at ±20º north and south of the geomagnetic equator and a minimum at this equator



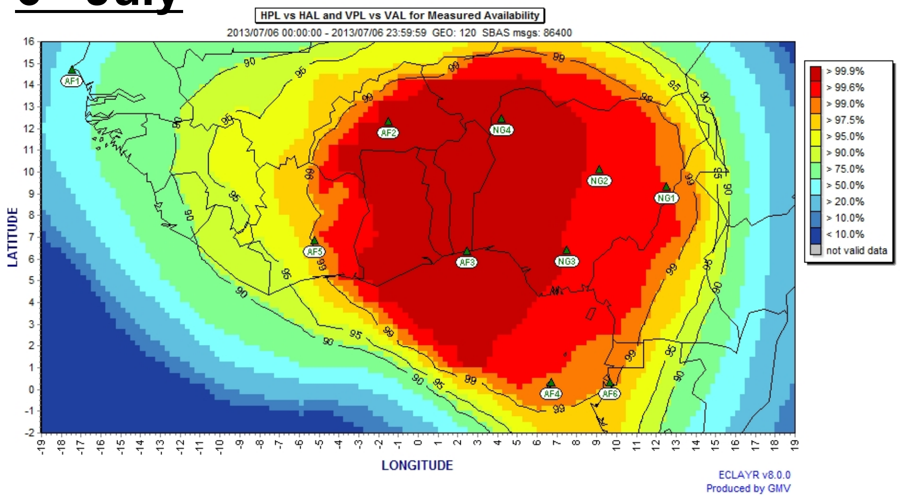
Features of Ionosphere over Africa (II)

- IEA is strongly influenced by:
  - solar and geomagnetic activity
  - daily, day-to-day and seasonal variations
  - geomagnetic storms, disturbances and irregularities
- The IEA development maximizes during equinoxes (March, April and September, October) and it is lower during solstice months
- Large number of indipendent parameters can be used to study Ionosphere variability and its causes:
  - Rate of Change / Rate of Change Index: ROT / ROTI
  - geomagnetic indices: Kp, Dst, ap
  - solar parameters: solar wind speed, IMF, Bz

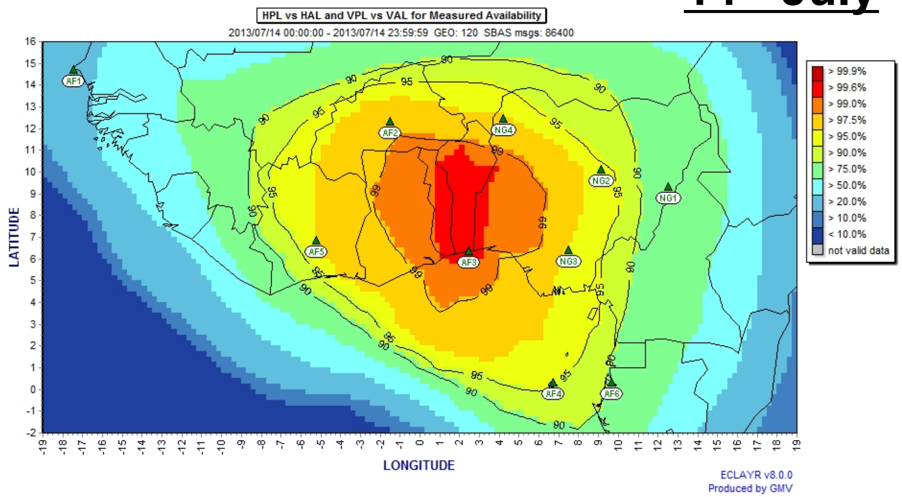
July 2013 – Low Latitude Algorithm – 24 hours graphs



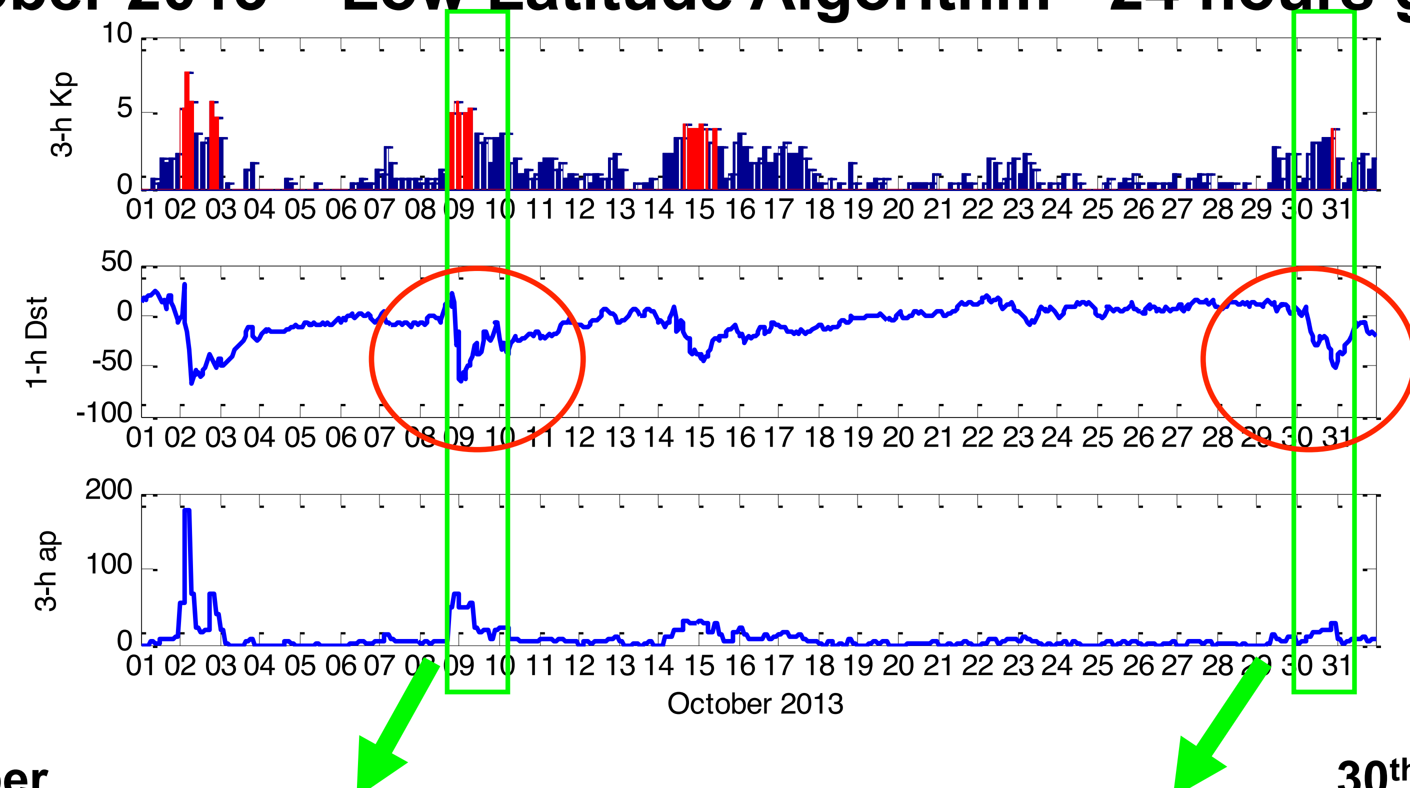
6th July



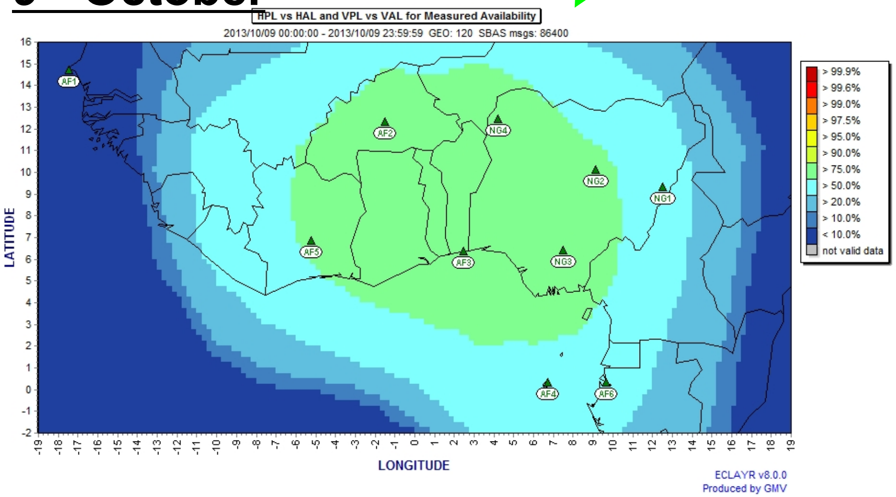
14th July



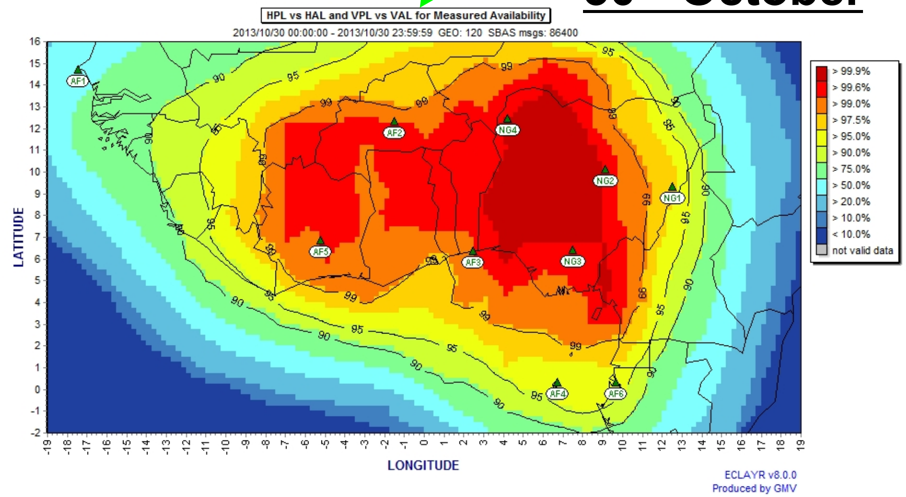
October 2013 – Low Latitude Algorithm - 24 hours graphs



9th October

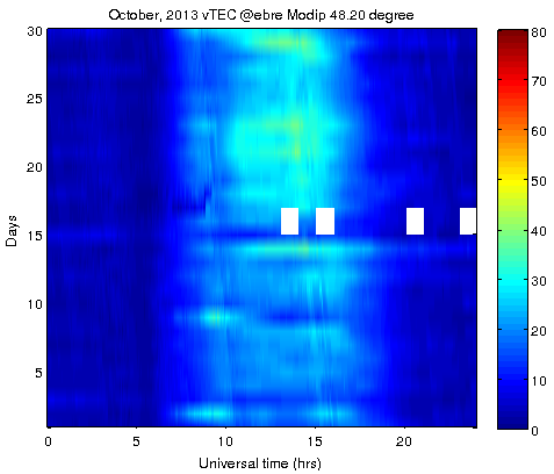


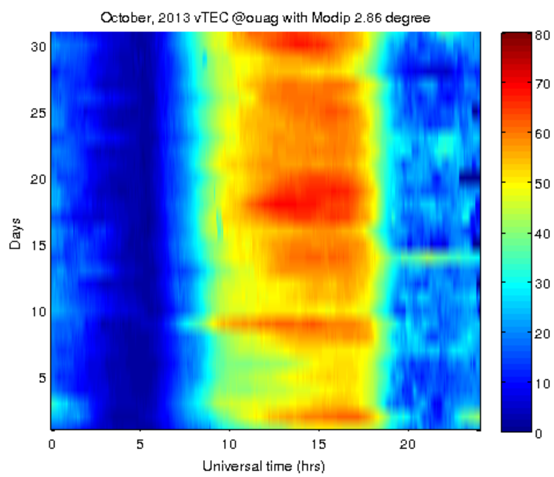
30th October

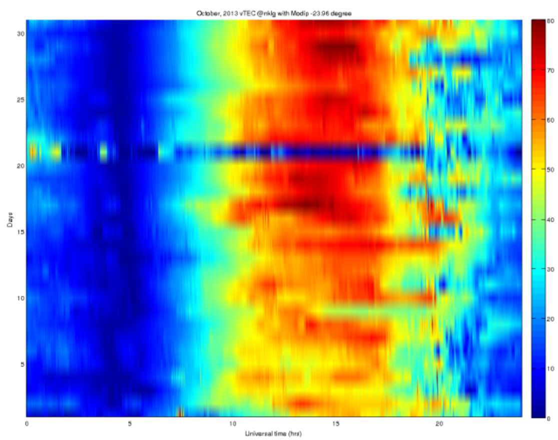


Effect of the Ionospheric Irregularities on SBAS Diurnal variation of VTEC at different geomag. latitudes (October 2013)

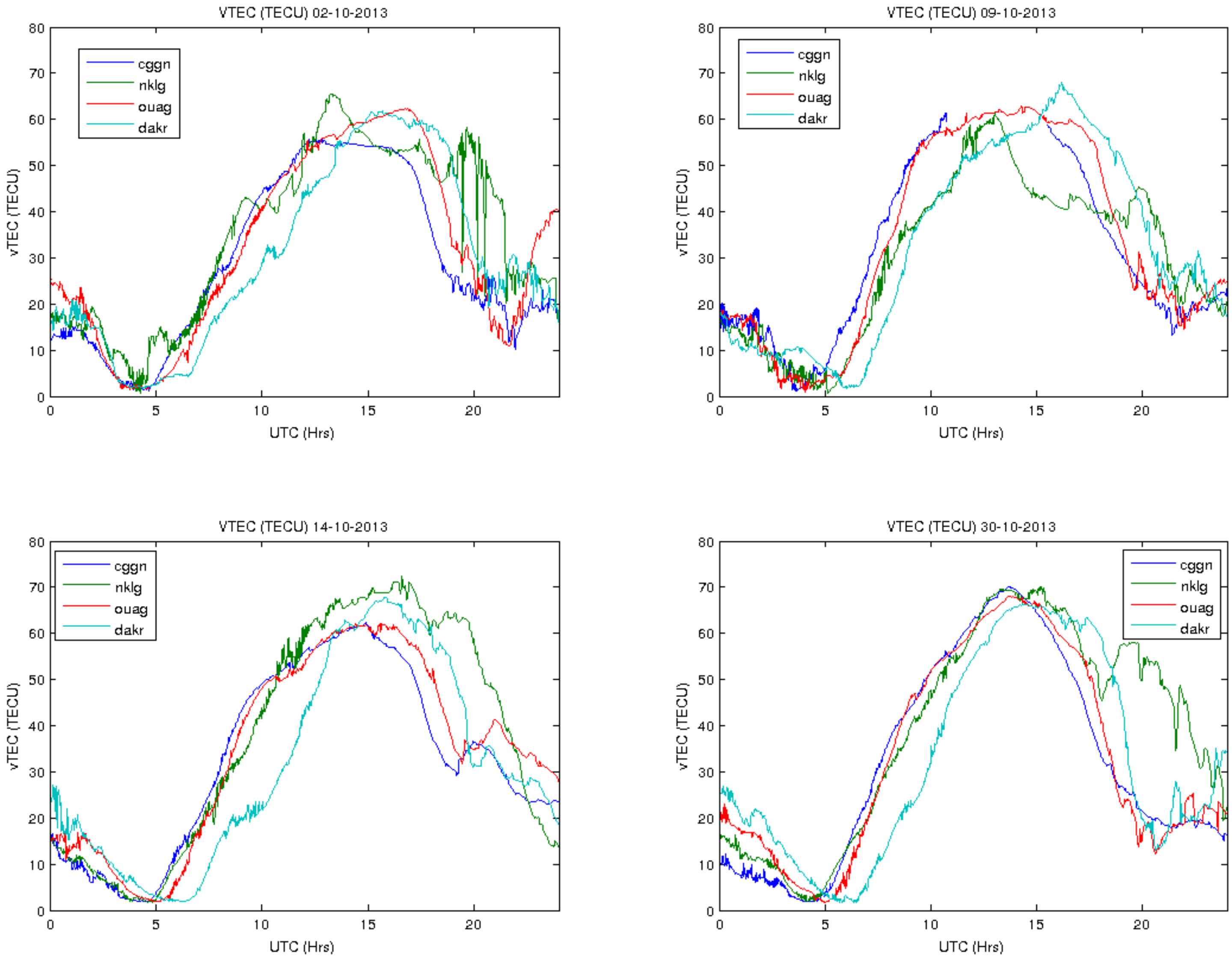
ebre 48.20 deg	ouag 2.86 deg	nklg -23.96 deg







Signature of storm on vTEC during October 2013 storms



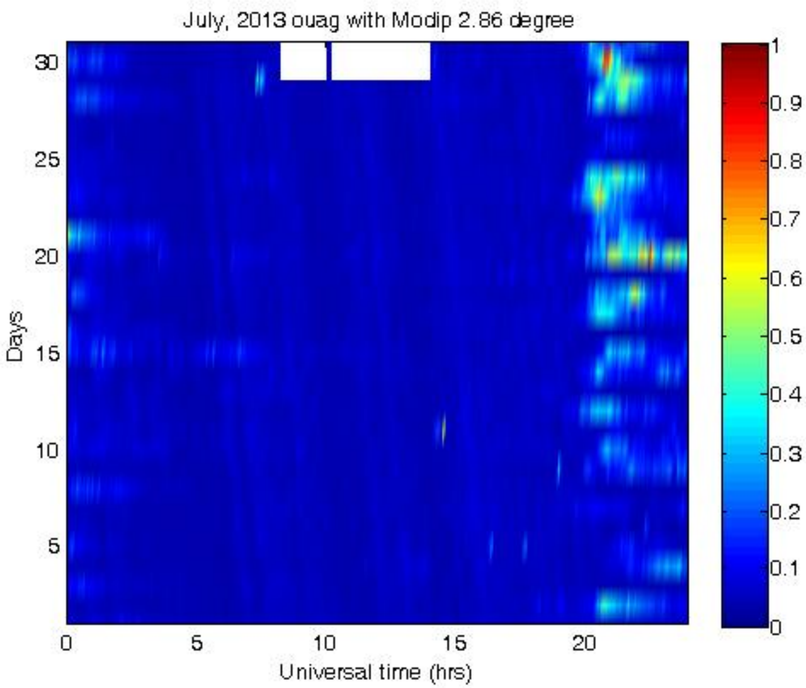
Rate of Change of TEC (ROT) / Index (ROTI)

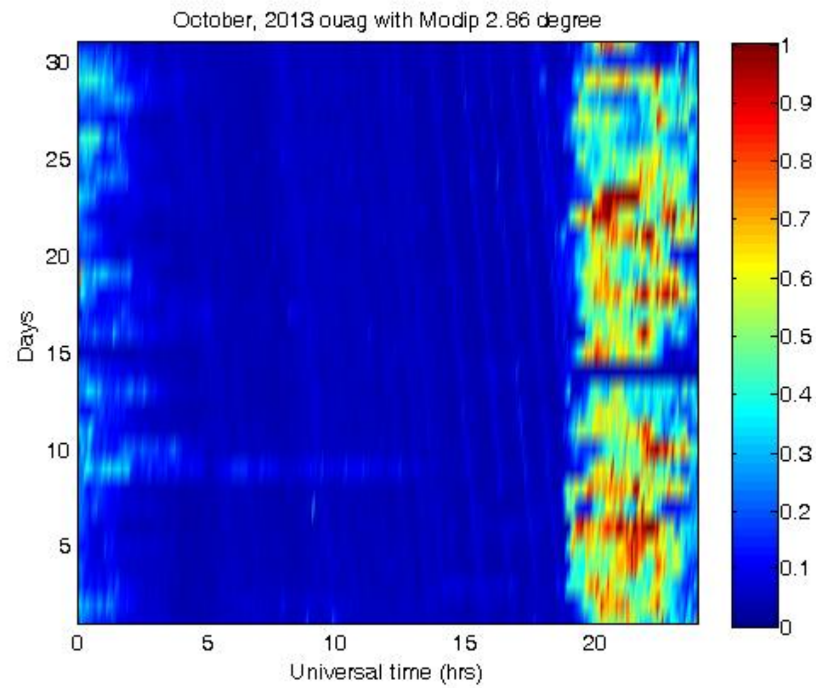
- Basu et al.(1999) referred to ROT and ROTI as a good proxy to estimate ionospheric scintillation
- This parameter was used by Jiyun et al. (2006) to deduce the presence of temporal gradient
- Chandra et al. (2009) as well used ROT to identify the signal which suffer severely from ionospheric gradient
- Ionospheric scintillation and gradient are more prevalence in low and equatorial region than middle and high latitudes
- This was estimated to study the behaviour of the ionosphere and its impact on GNSS-SBAS performance

Mean ROTI of all visible satellites for ouag station at 15º elevation mask

July 2013

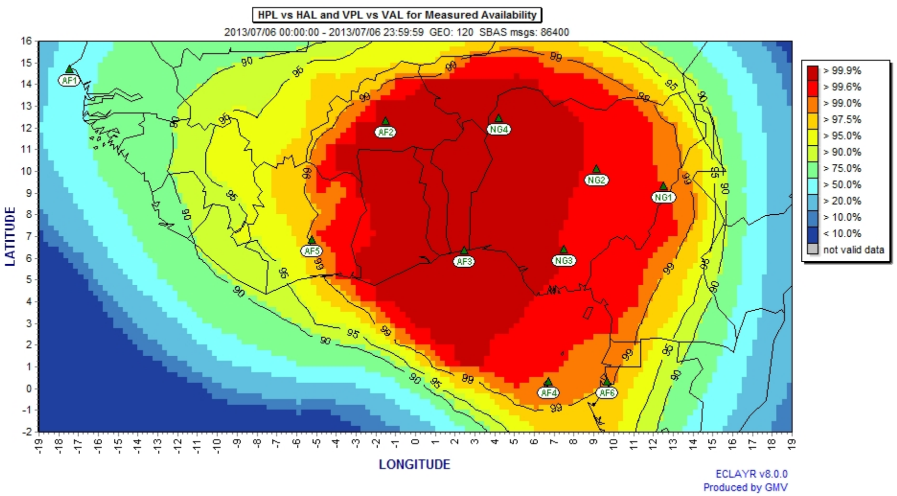
October 2013

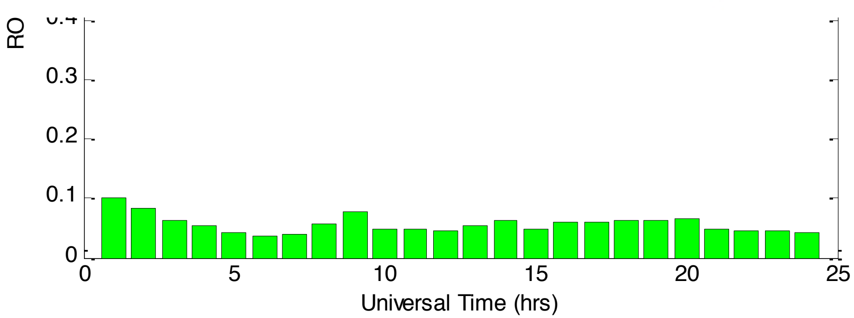




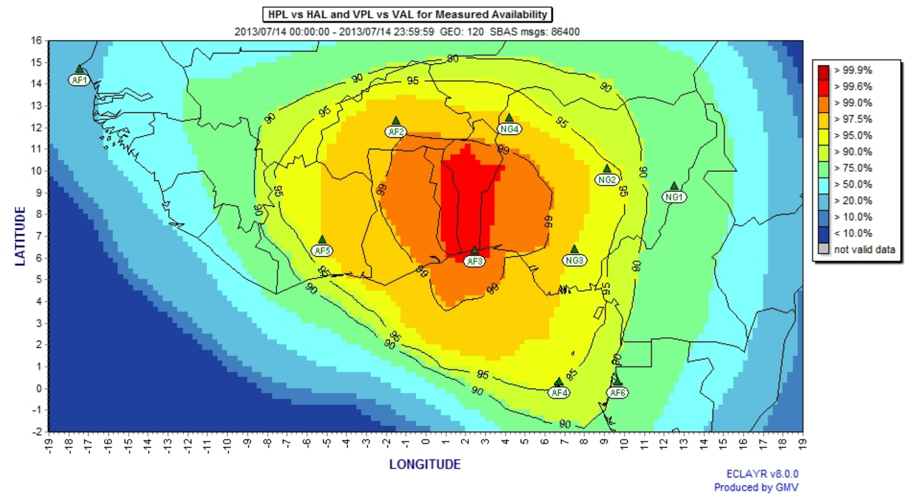
ROTI for all visible satellites in July 2013 at 15º elevation mask

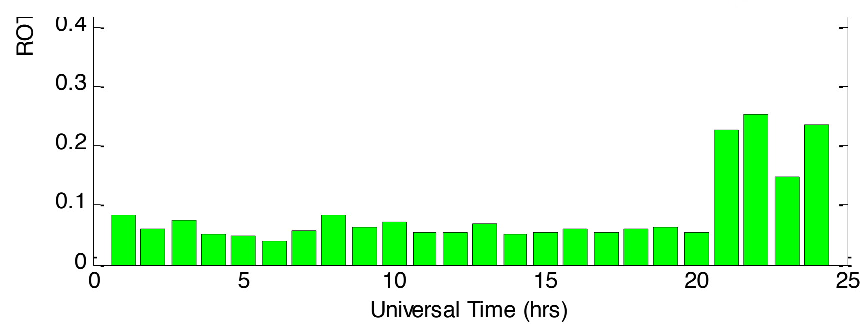
Storm time with inhibition of





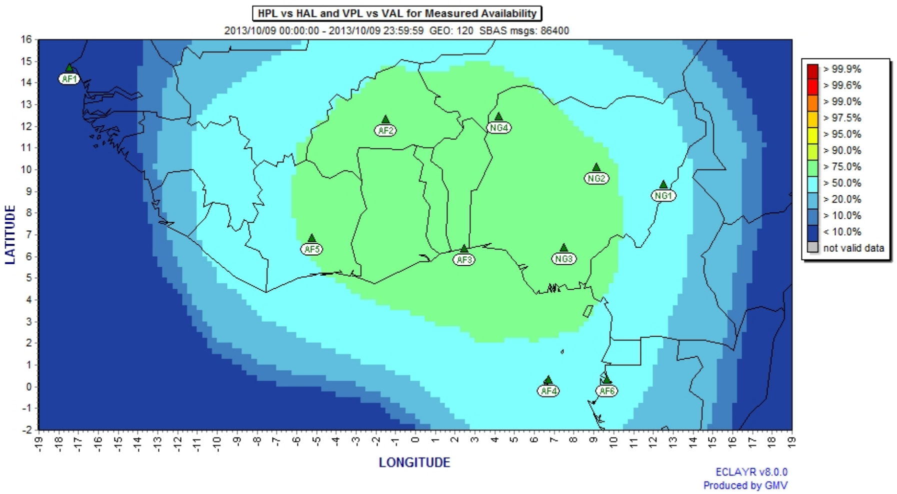
Storm time with enhancement

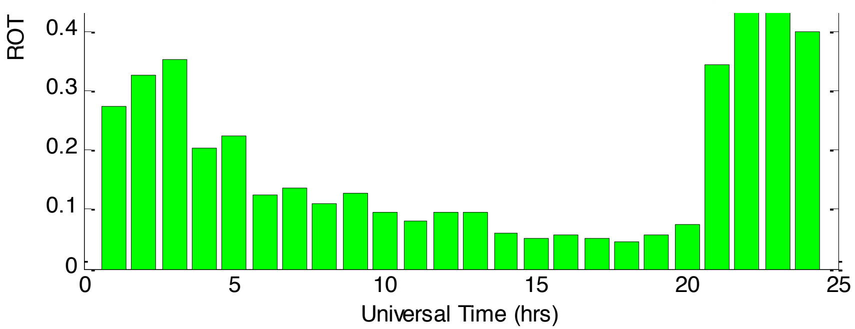




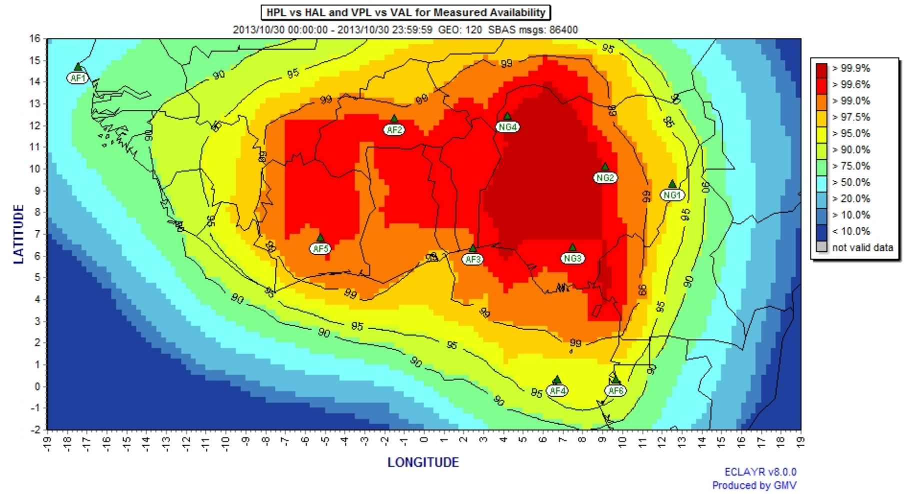
ROTI for all visible satellites in October 2013 at 15º elevation mask

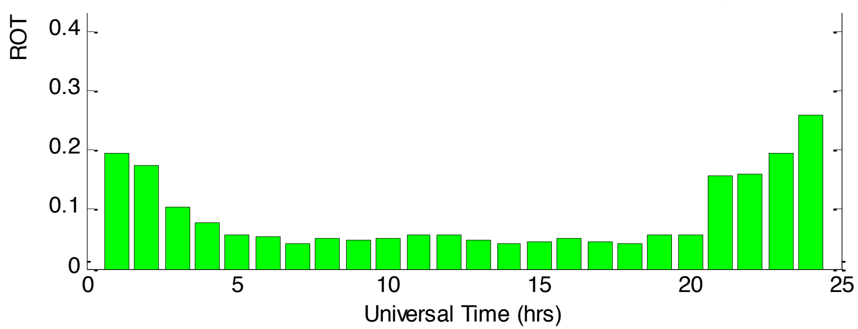
Storm time with enhancement in





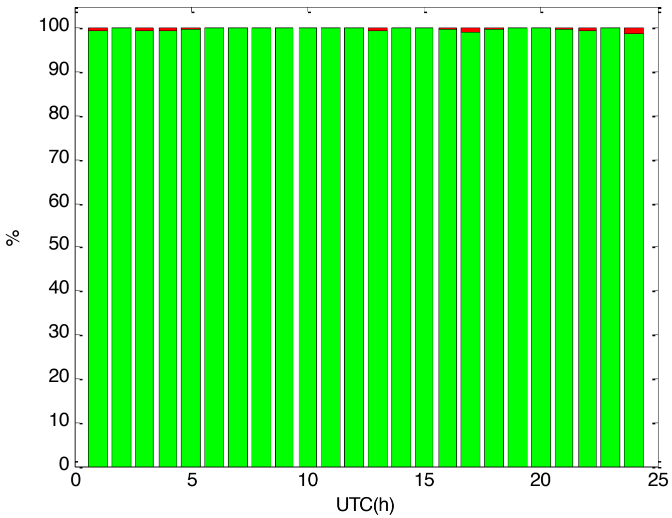
Storm time with inhibition of

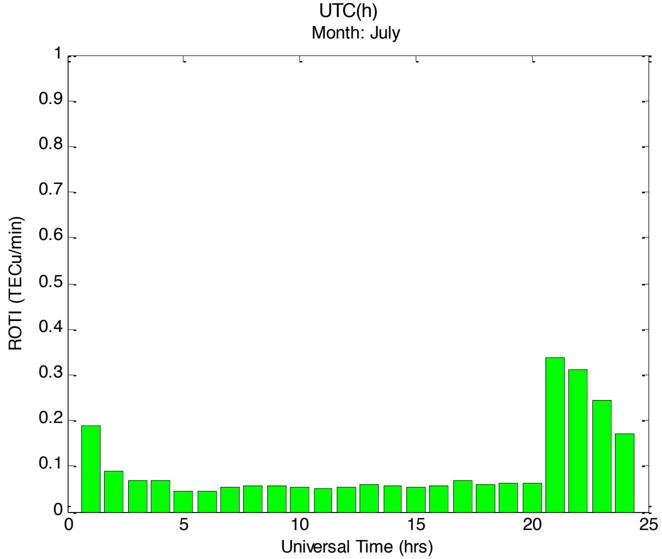




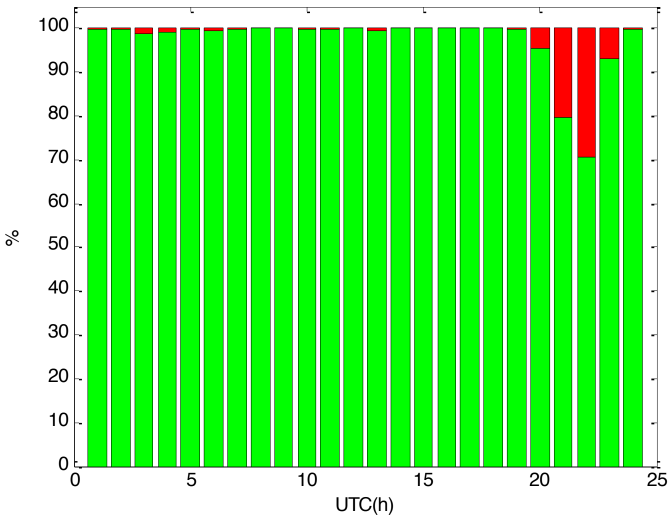
Comparison between monthly system status and monthly ROTI

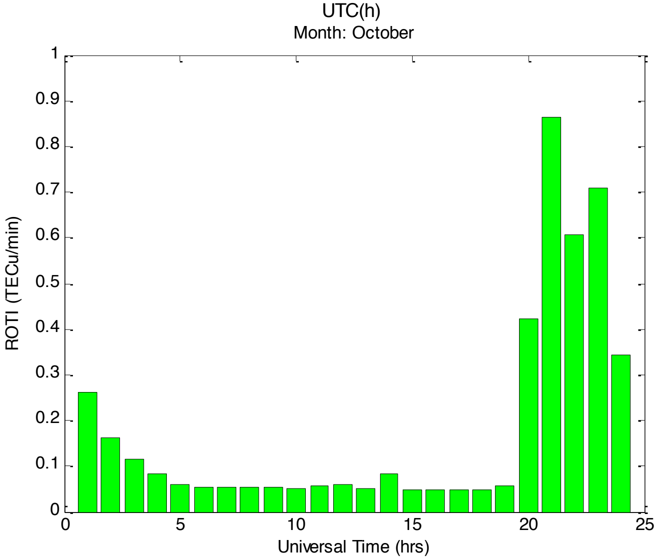
July 2013





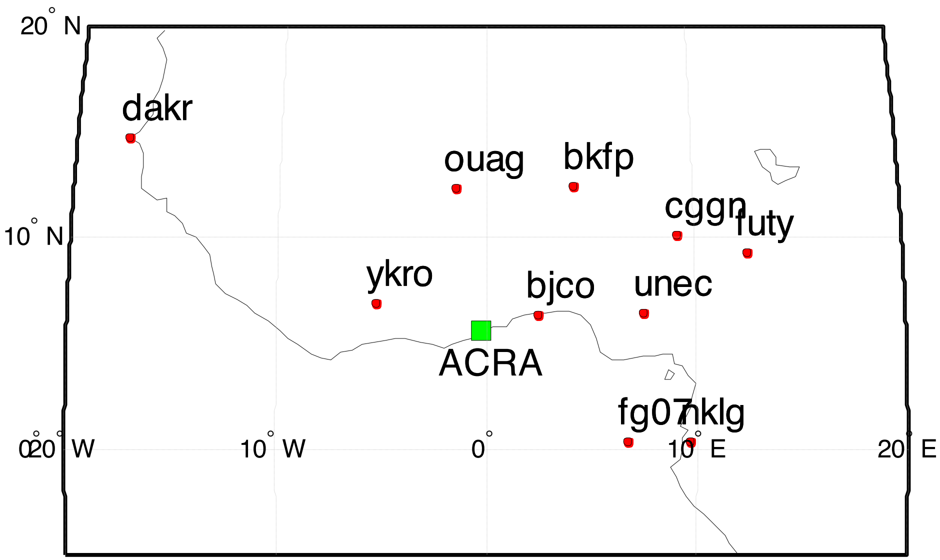
October 2013





Analysis of user level performance with **low-latitude algorithm**

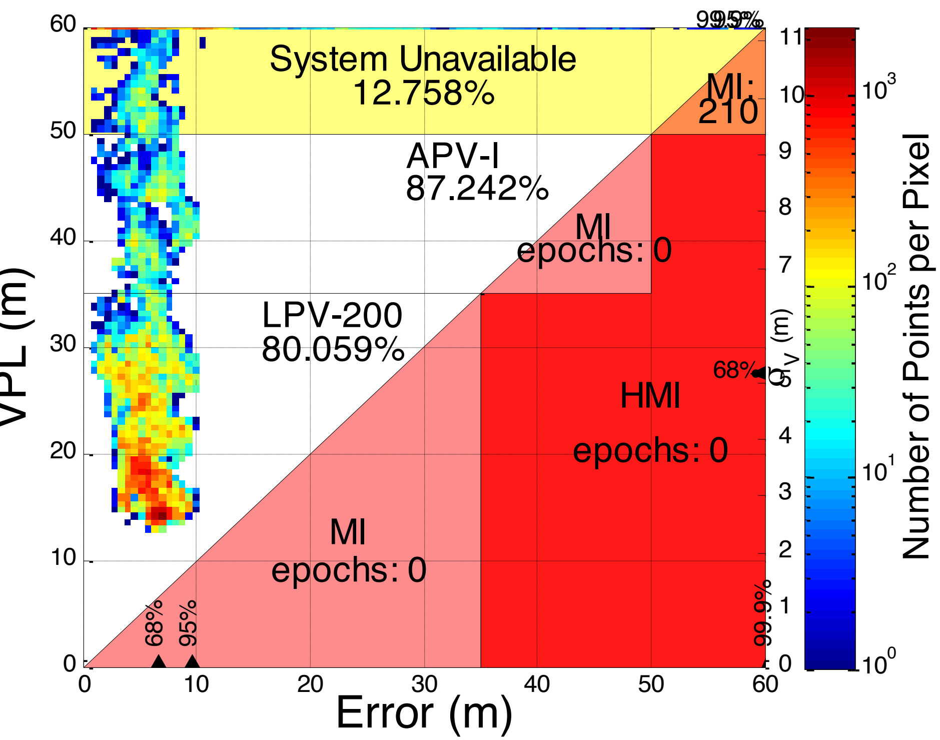
- Selection of an Independent station located at **ACCRA** (Ghana)



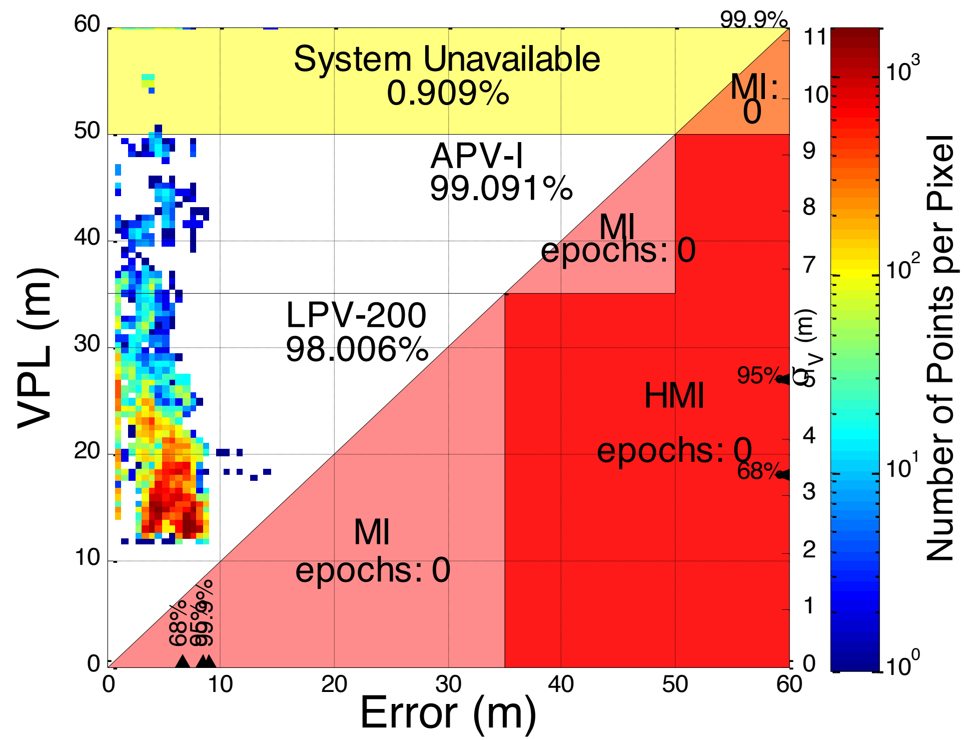
- Analysis of user performance at two storms periods in October 2013:
  - **October 9th 2013**
  - **October 14th 2013**

Stanford diagram at user located in Accra

09-10-2013

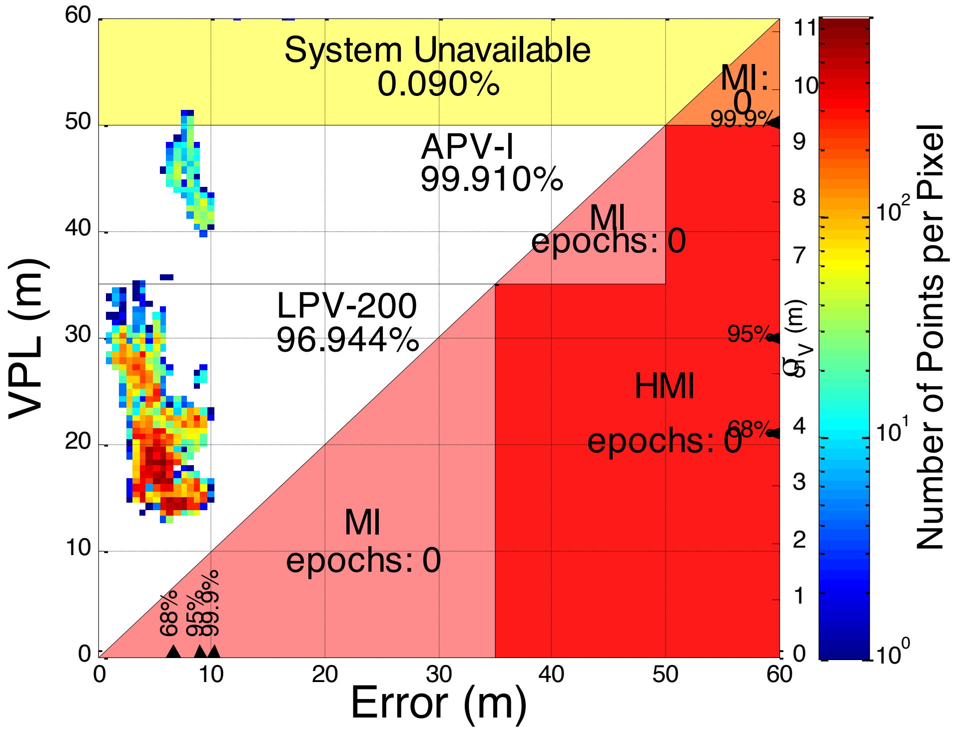


30-10-2013

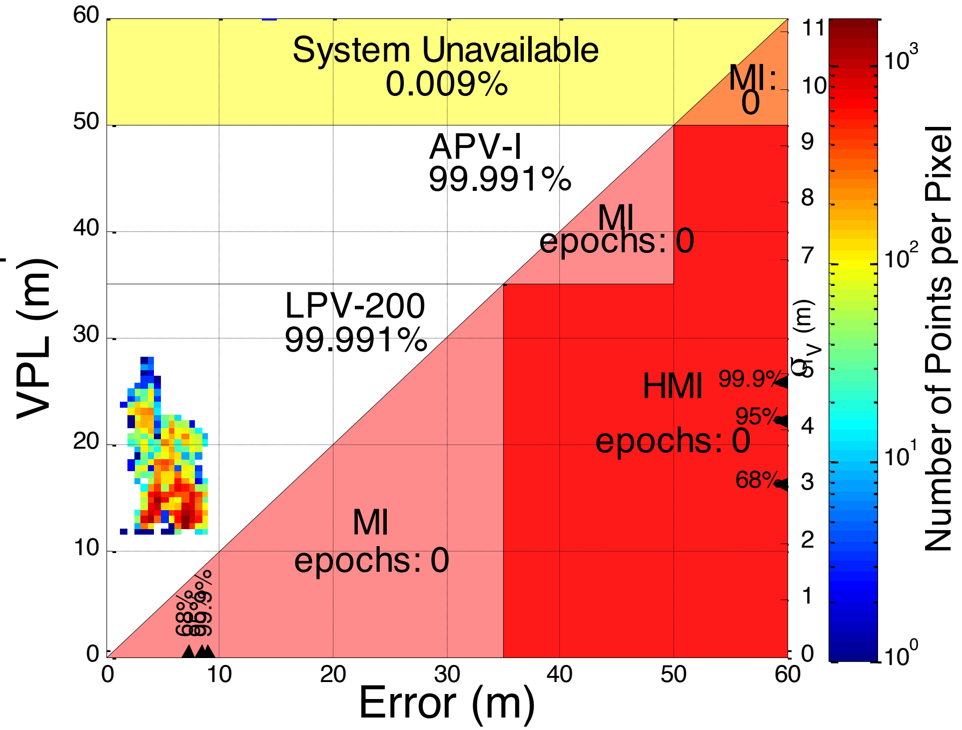


Stanford diagram at user located in Accra

09-10-2013
(4:00 – 18:00 UTC)

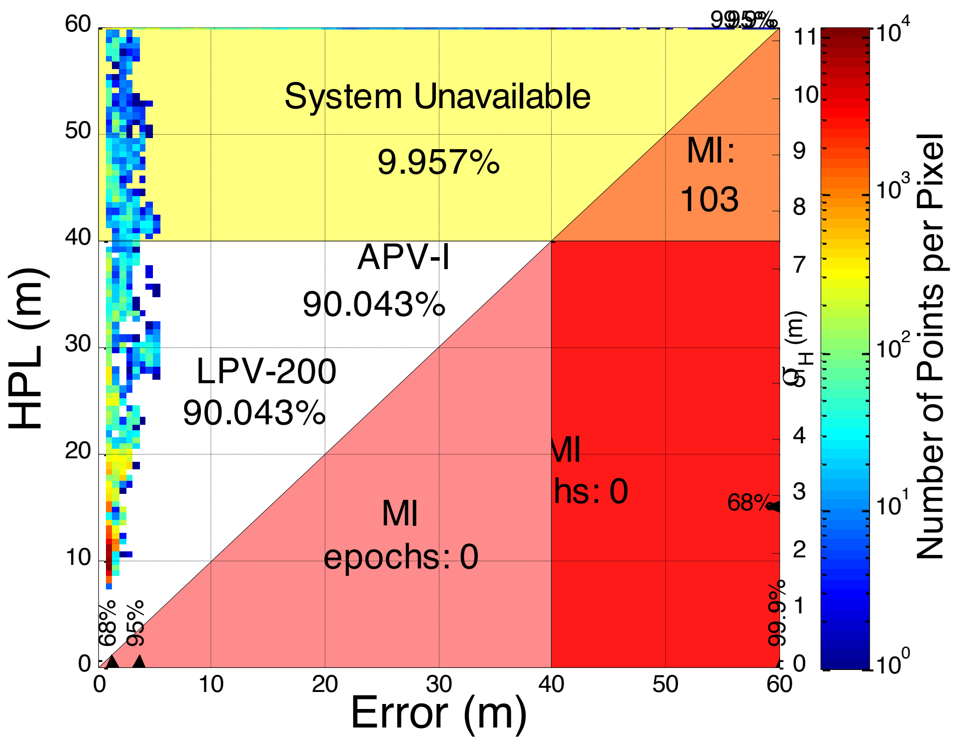


30-10-2013
(4:00 – 18:00 UTC)

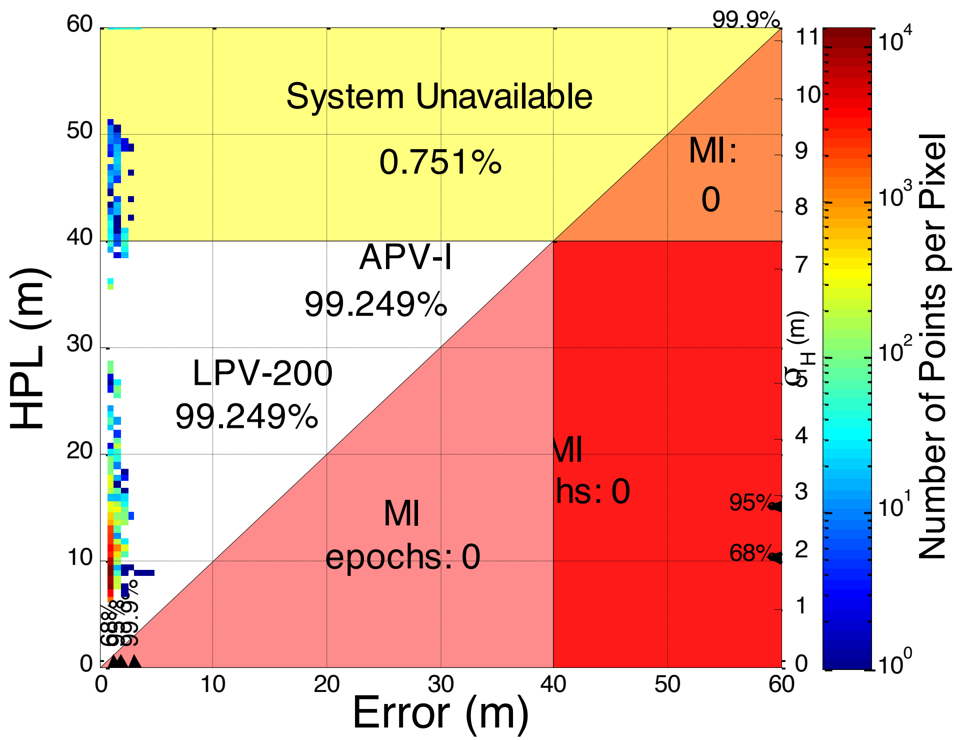


Stanford diagram at user located in Accra

09-10-2013

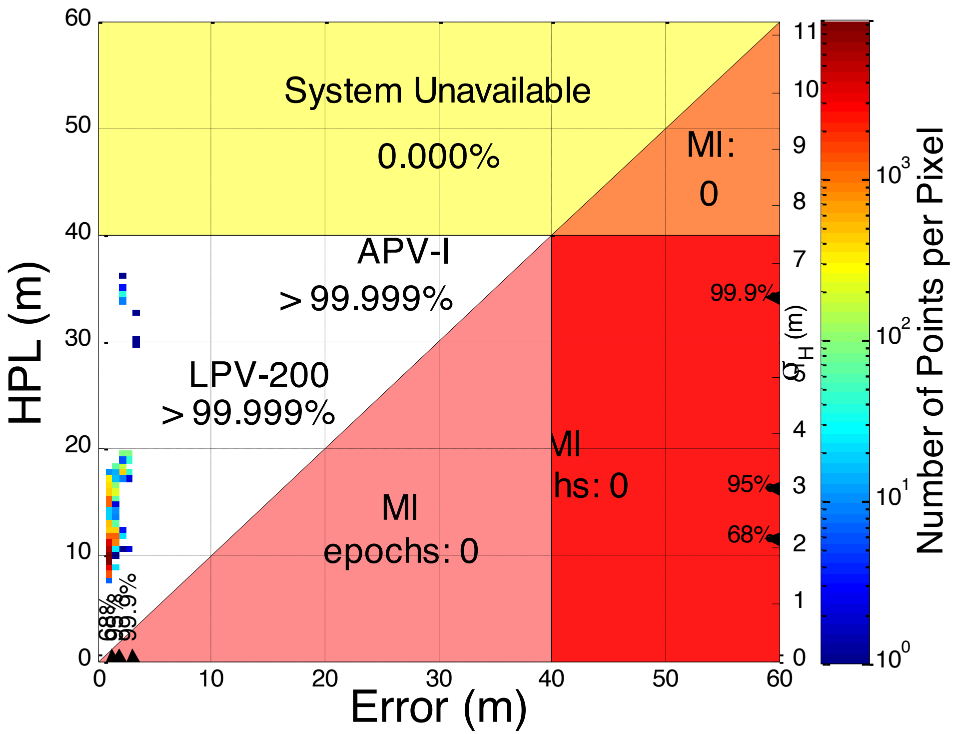


30-10-2013

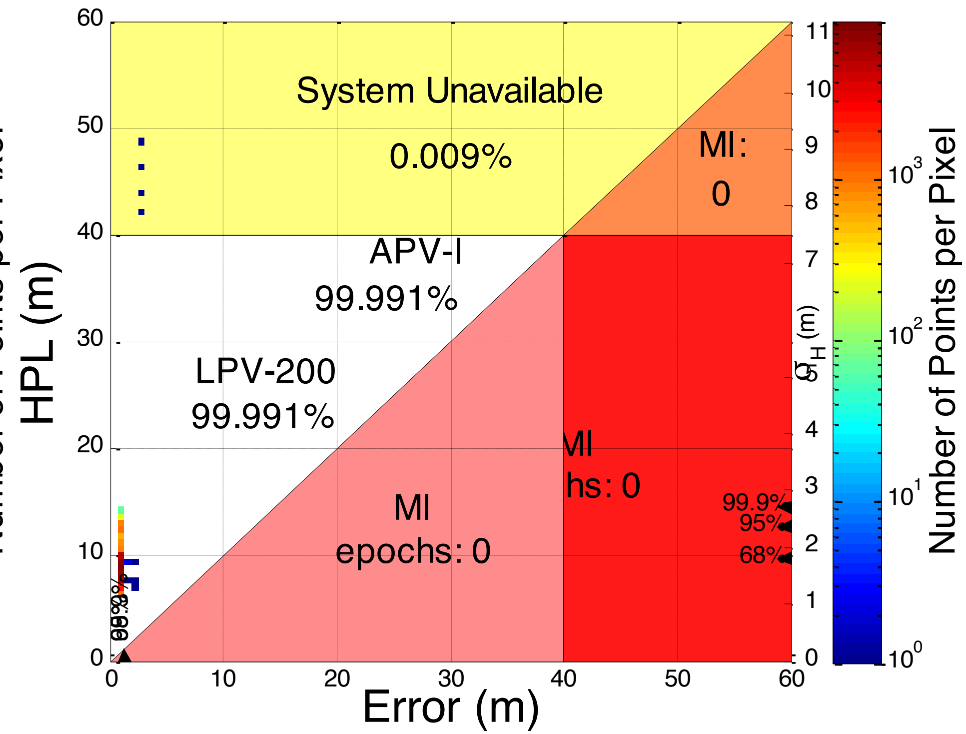


Stanford diagram at user located in Accra

09-10-2013
(4:00 – 18:00 UTC)



30-10-2013
(4:00 – 18:00 UTC)



Conclusions

- Results indicate that during the solstitial month, the SBAS system could provide 99% APV-I availability for 24 hours in a certain area of service while in the equinoctial month this would be generally reduced to 14 hours from 04:00 to 18:00 UTC. This is critically in acordance with the level of irregularities.
- The study shows that **ROT/ROTI** parameters are a good proxy for the presence of ionospheric irregularities and their effect on the system performance.
- It is expected that the low-latitude algorithm could be optimized for the African region improving its performance.
- The design of a better distribution of stations by means of the assessment with a synthetic ionosphere (produced with NeQuick) could also improve the system performance.

Thank you for your attention