Simultaneous Observations of EGNOS and GPS Amplitude Scintillations over Equatorial Africa

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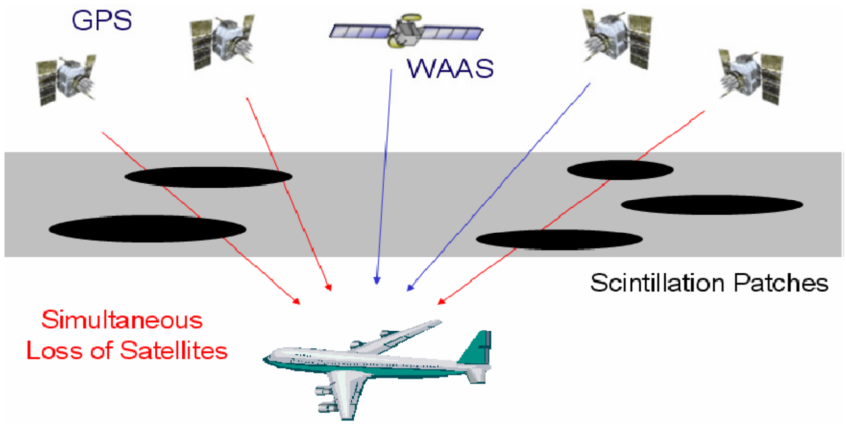
Outlines

- Introduction
- Data Resources
- Results
- Conclusions
- Proposal
- Acknowledgements

Introduction

Based on its safety and economic benefits, GNSS/PBN is at the verge of replacing the conventional terrestrial Nav infrastructures in the aviation Industry (Akala et al., 2012, Radio Sci.).

For these reasons, ICAO has mandated all of its regions, under the auspices of regional Ionospheric Studies Task Force (ISTF) to establish a framework for understanding the phenomenology of ionospheric effects on GNSS in each region, with a view to proffering mitigation strategies to their impacts on GNSS aviation applications.



Ionospheric Effects on GNSS Aviation

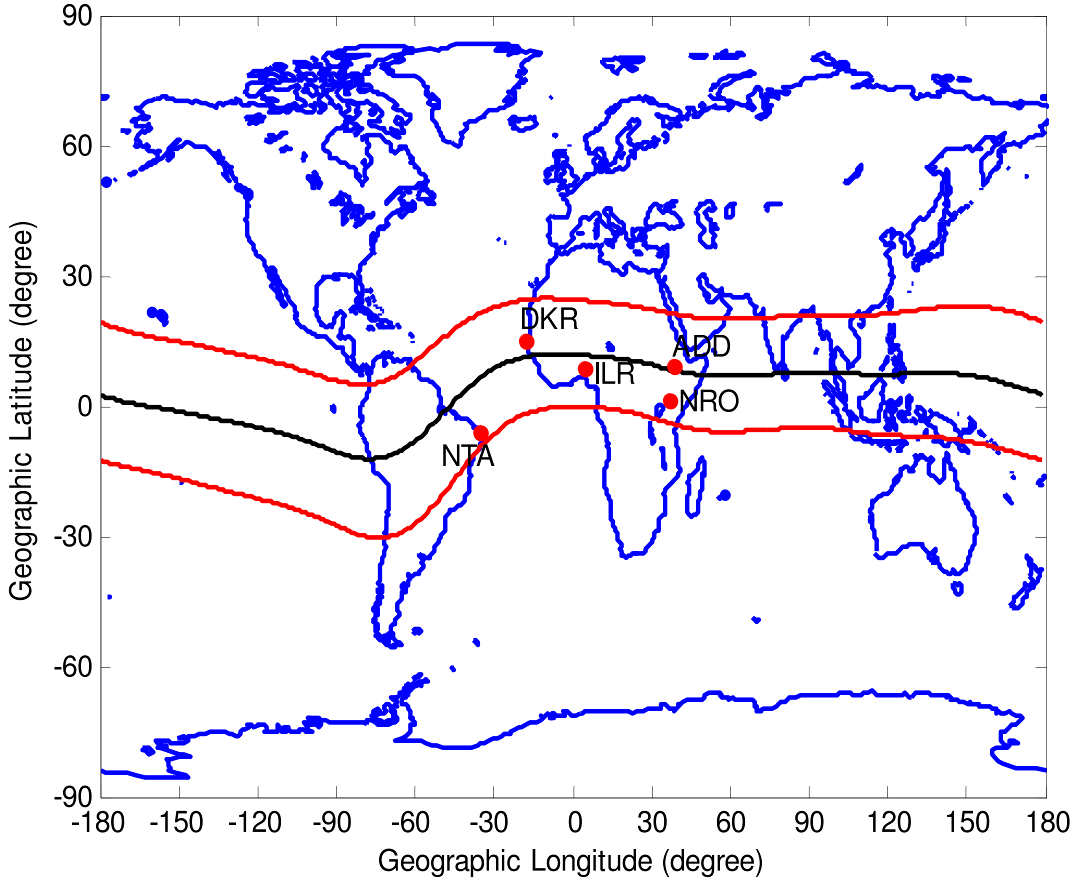
Group delay effect: It is currently being resolved by the dual frequency (DF) mechanisms of modern GNSS receivers.

Scintillation effect: It is not yet resolved due to its temporal, daily, monthly, seasonal, geomagnetic activity, solar activity, and regional variations that have not yet been adequately addressed, particularly in the African region.

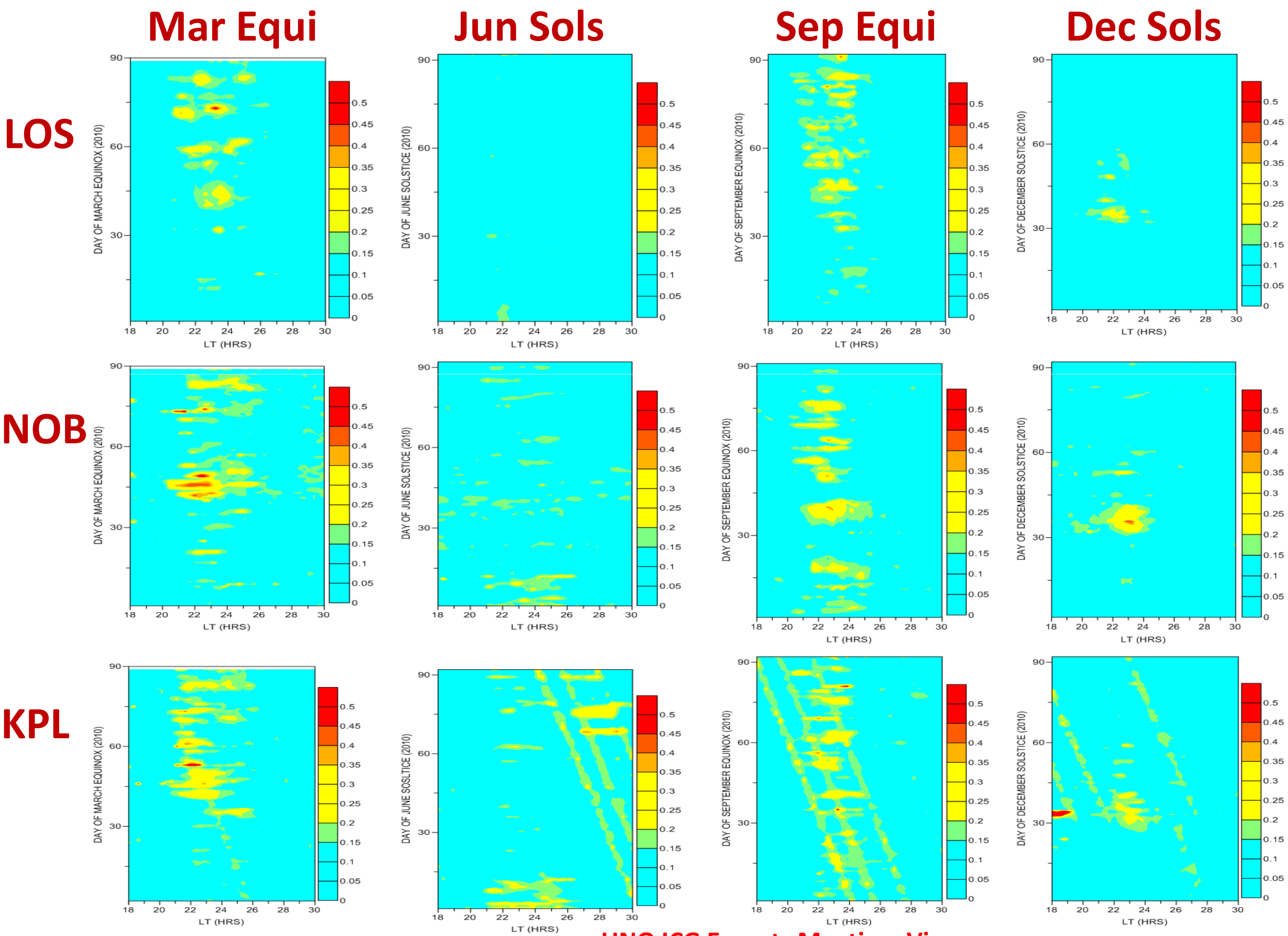
On a global scale, *Burke et al.*, 2004; *Gentile et al.*, 2006; 2011; *Hei et al.*, 2005; *Kil et al.*, 2009; *Akala et al.*, 2013 have reported more equatorial scintillation events in the African longitude than other longitudes. Recently, *Tsunoda et al.* (2015, JGR) suspected that orographic sources might be responsible for these variations. Evidence is required for concrete conclusions.

Data Resources

GPS Receivers
2012/2013
amp. scint data



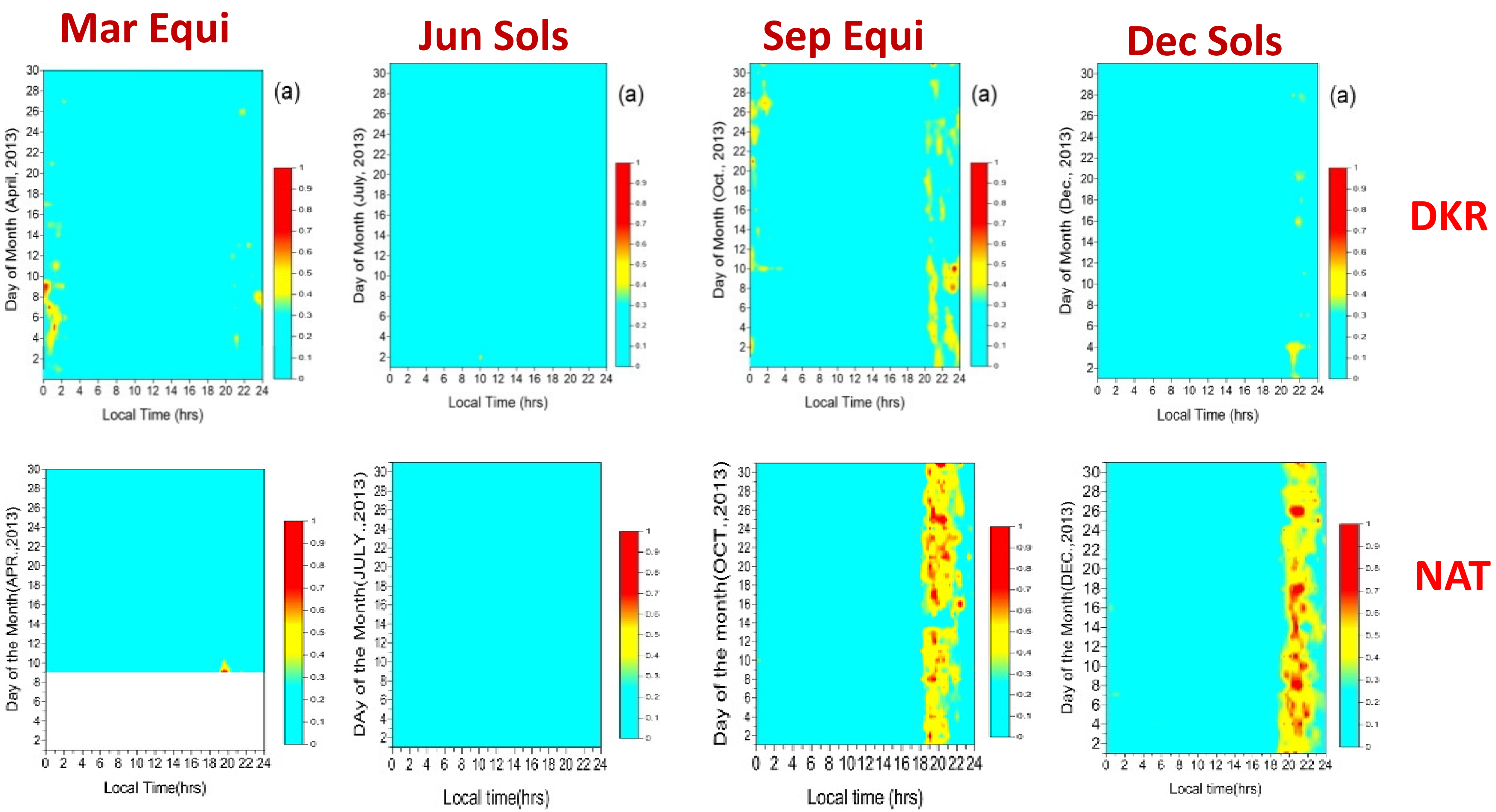
Variations of Equatorial African Amplitude Scintillations (2010)



Increasing Mag. Lat ~3ºS – 10ºS

Akala et al. (2015, Astrophs. & Space Sci.)

Variations of Equatorial Amplitude Scintillations (Dakar and Natal, 2013)



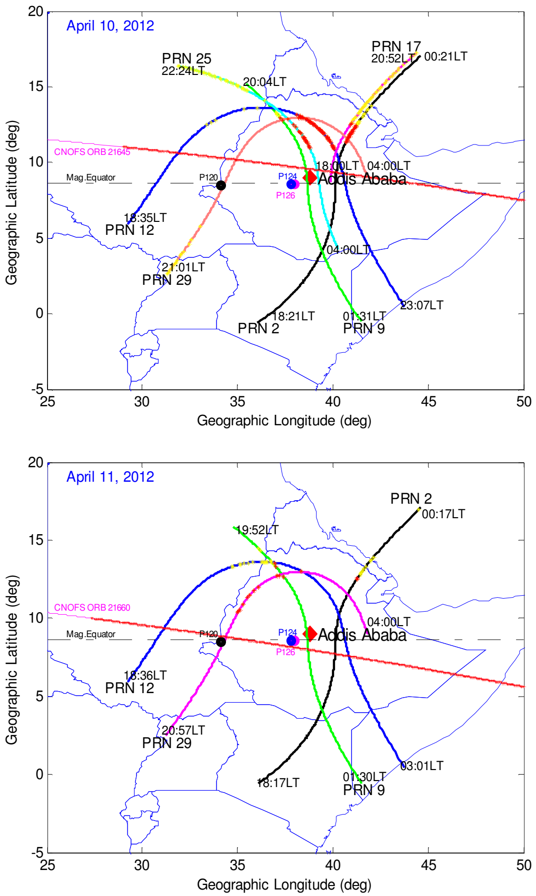
Akala et al. (Submitted, Space Weather)

Comparison of results of *Akala et al.* [2015] with the Observed Scintillation Events at Dakar and Natal, Brazil

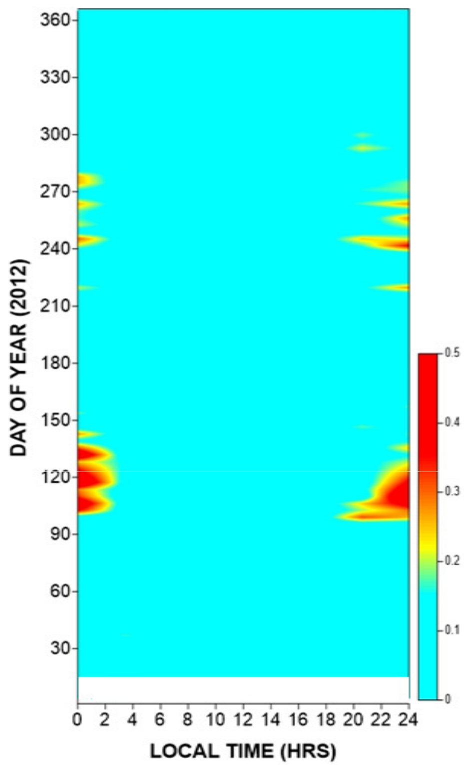
Study/ Data Coverage	Receiver location(s)	Scintillations active months	Non-scintillations months	Post-sunset scintillations	Diagonal features on data
Akala et al. [2015] 2009–2011	Lagos (6.48°N, 3.27°E, Mag. Lat: 4.95°S), Nigeria Nairobi (1.16°S, 36.80°E, Mag. Lat: 10.65°S), Kenya Kampala (0.30°N, 32.50°E, Mag. Lat: 11.12°S), Uganda	Mar., Apr., Sep., and Oct. Active months of bubble occurrences over the stations [*Burke et al.*, 2004; *Huang and Hairston*, 2015]	Jan., Jun., Jul., and Dec. Non-bubble months over the stations [*Burke et al.*, 2004; *Huang and Hairston*, 2015]	Evident in Nairobi and Kampala data (mainly at weak level) (attributed to MSTID propagating equator-wards from the mid-latitude, presence of sporadic E, and neutral winds)	Evident in Kampala data (attributed to multipath noises due to the antenna environment)
Current study 2012–2014 (Jan. and Feb.)	Dakar (14.75°N, 17.45°W, Mag. Lat: 5.88°N), Senegal	Mar., Apr., Sep., and Oct. Active months of bubble occurrences over the station [*Burke et al.*, 2004; *Huang and Hairston*, 2015]	Jun. and Jul. Non-bubble months over the station [*Burke et al.*, 2004; *Huang and Hairston*, 2015] Climatology similar to the report of *Akala et al.* [2011]	Scanty occurrences (at weak level)	Non-existent

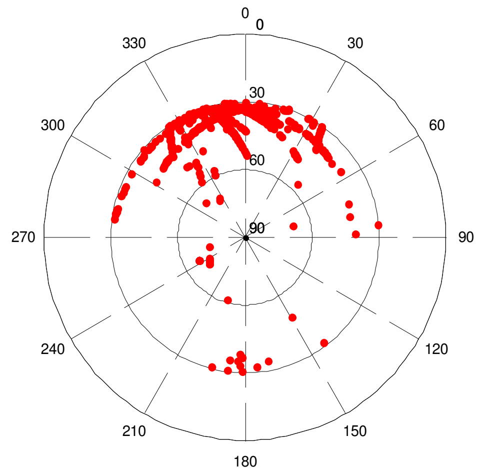
Akala et al. (Submitted, Space Weather)

Ionospheric scintillations over Addis Ababa (2012)



IPP traces of satellites that experienced scintillations and C/NOFS tracks over Addis Ababa

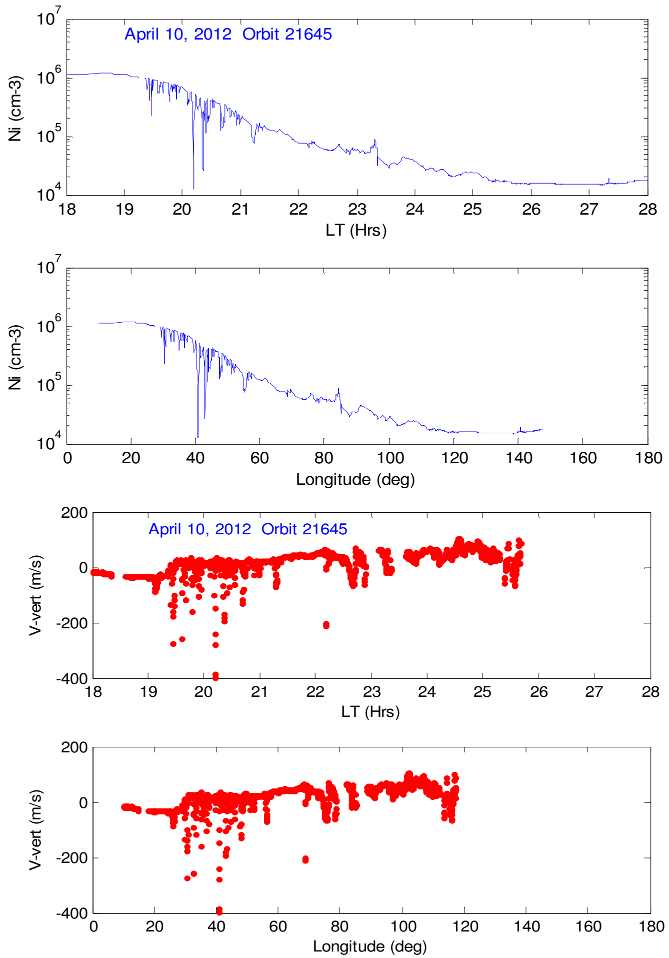




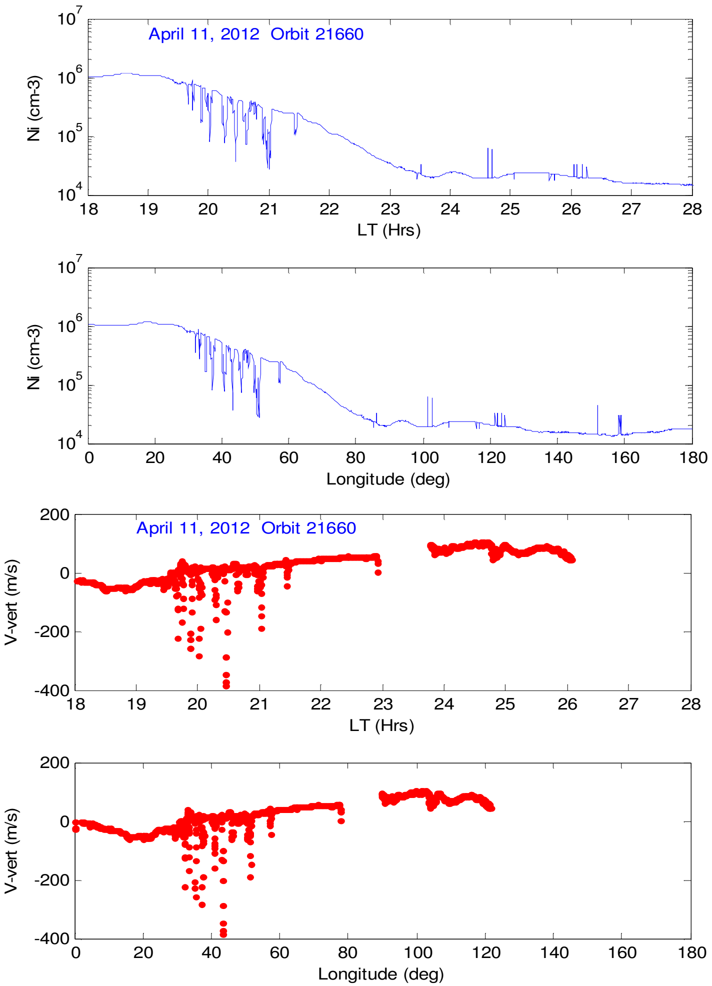
Polar plots of high elevation (≥ 30°) scintillations (S4 ≥ 0.5) over Addis Ababa during 2012

Akala et al. (Submitted, ANGEO)

Ion density and vertical ion drift velocity measured on-board CNOFS



April 10, 2012



April 11, 2012

IPP, Azimuth, & Elevation Coordinates of SBAS at the Five Stations

STATIONS	EGNOS		EGNOS		EGNOS		WAAS	
	PRN 120		PRN 124		PRN 126		PRN 138	
	IPP LAT (°)	IPP LONG (°)	IPP LAT (°)	IPP LONG (°)	IPP LAT (°)	IPP LONG (°)	IPP LAT (°)	IPP LONG (°)
ADDIS ABABA	8.49	34.15	8.55	37.79	8.55	38.01	-	-
NAIROBI	-1.19	32.64	-	-	-	-	-	-
ILORIN	8.03	4.82	-	-	-	-	-	-
DAKAR	13.89	342.65	13.85	345.25	13.83	345.65	-	-
NATAL	-5.53	325.9	-	-	-	-	-.5.4	314.39

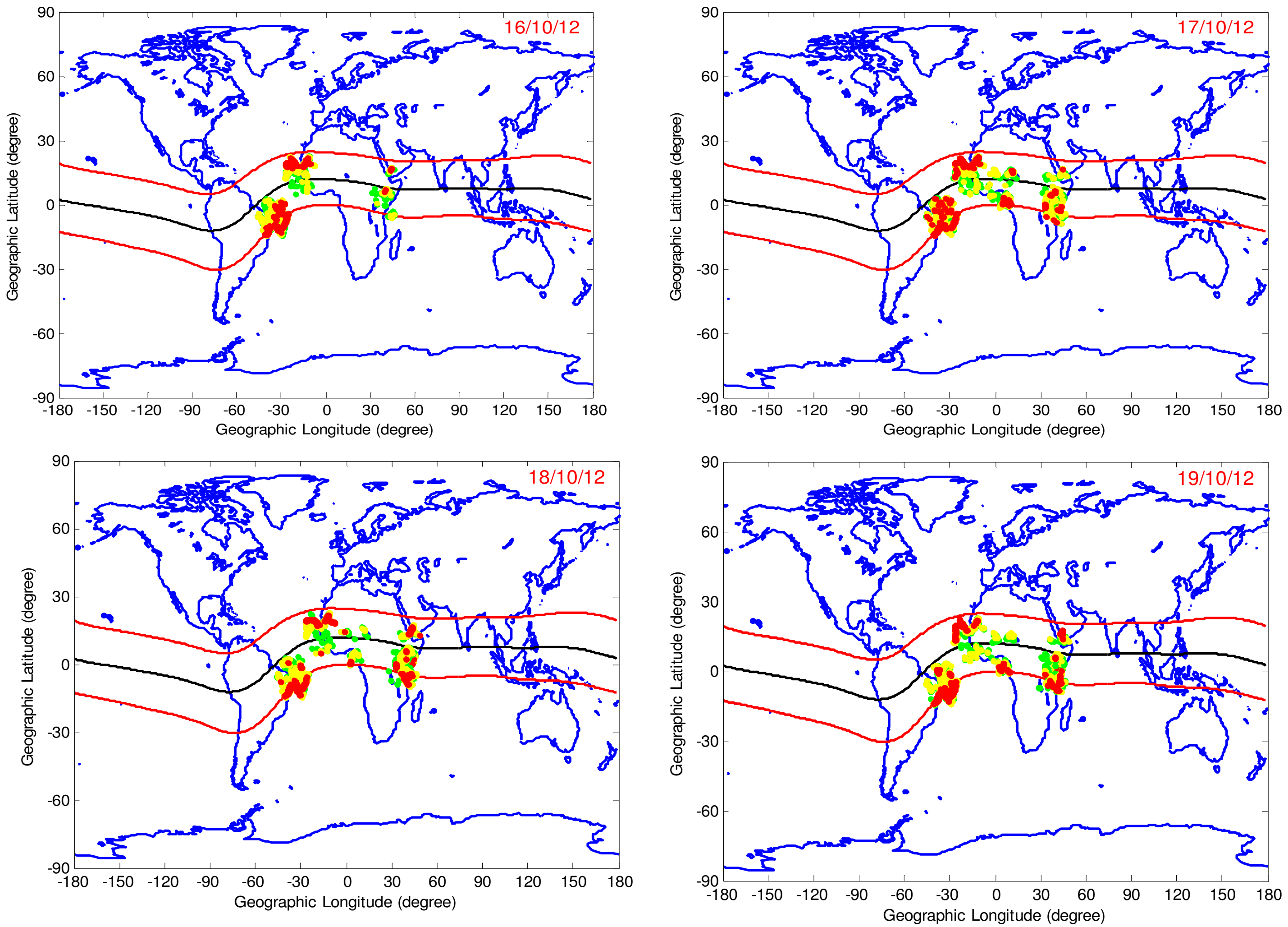
STATIONS	EGNOS		EGNOS		EGNOS		WAAS	
	PRN 120		PRN 124		PRN 126		PRN 138	
	Elev. Ang. (°)	Azim. Ang. (°)	Elev. Ang. (°)	Azim. Ang. (°)	Elev. Ang. (°)	Azim. Ang. (°)	Elev. Ang. (°)	Azim. Ang. (°)
ADDIS ABABA	27.6	263.6	67.2	243.4	70.9	237.1	-	-
NAIROBI	30.2	271.0	-	-	-	-	-	-
ILORIN	64.5	248.2	-	-	-	-	-	-
DAKAR	72.7	172.1	42.4	107.3	38.6	105.3	-	-
NATAL	74.3	65.9	-	-	-	-	9.3	271.9

Samples of Scintillation Observations at 5 Equatorial Stations during the equinox of 2012

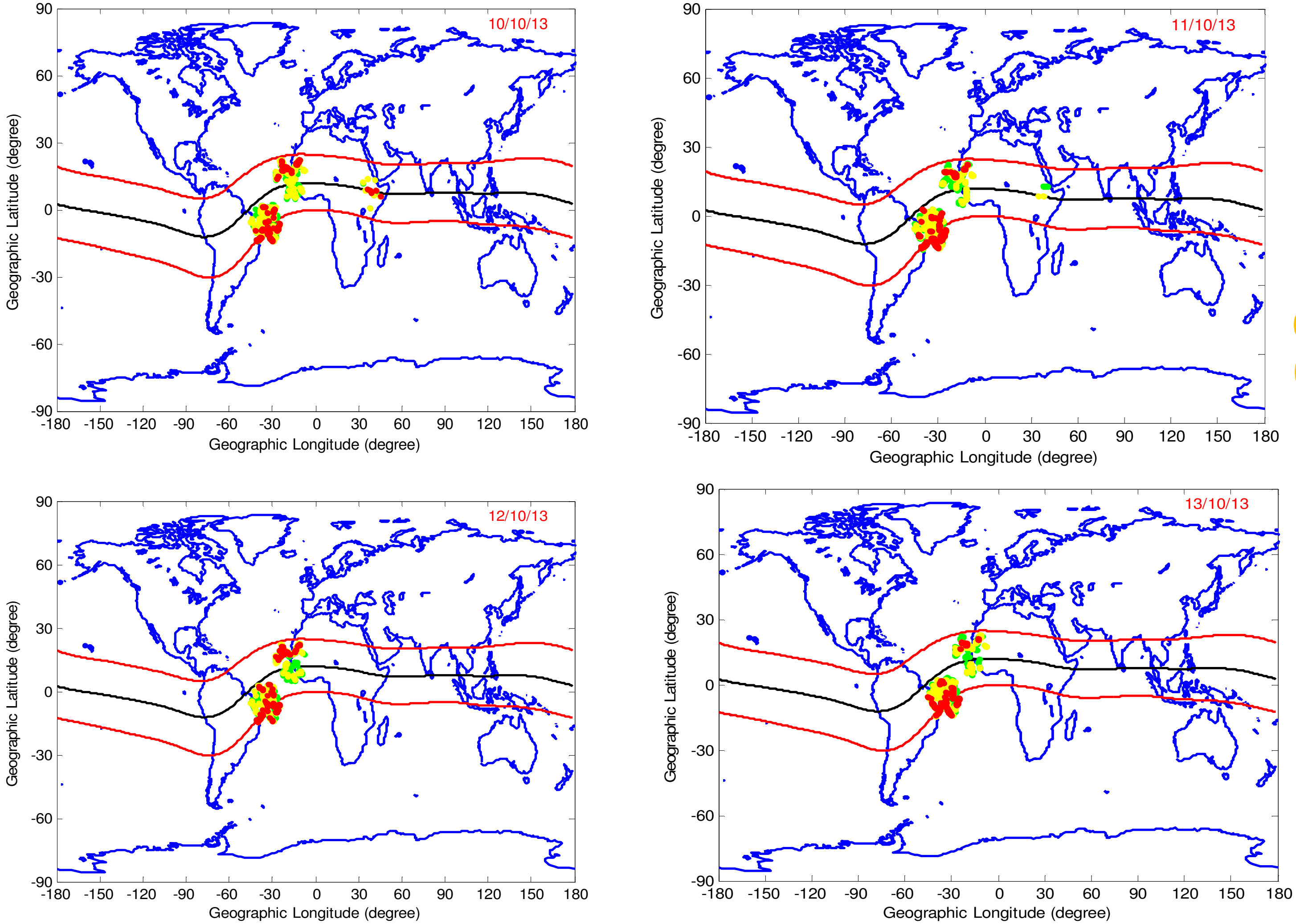
S4 > 0.7
(Int. Scint.)

0.4<=S4 > 0.7
(Mod. Scint.)

04<=S4 > 0.7
(Mod. Scint.)



Samples of Scintillation Observations at 3 Equatorial Stations during the equinox of 2013

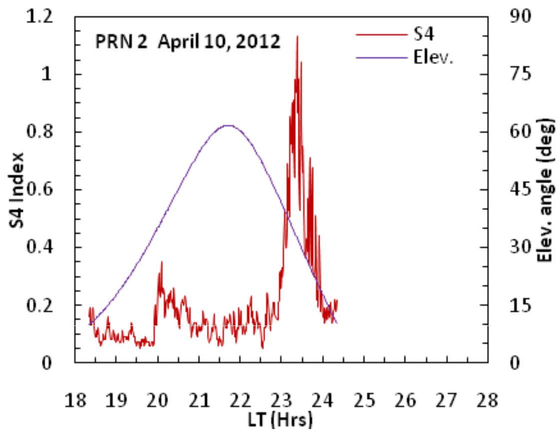


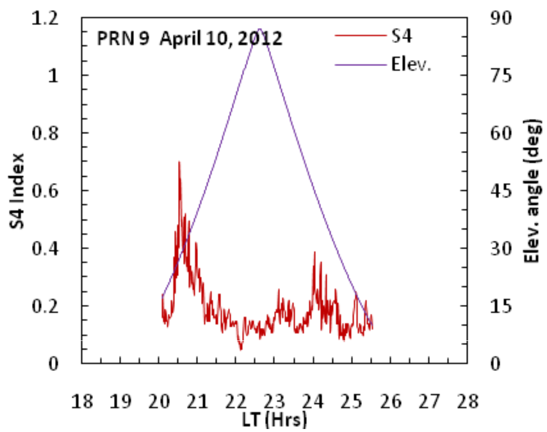
S4 > 0.7
(Int. Scint.)

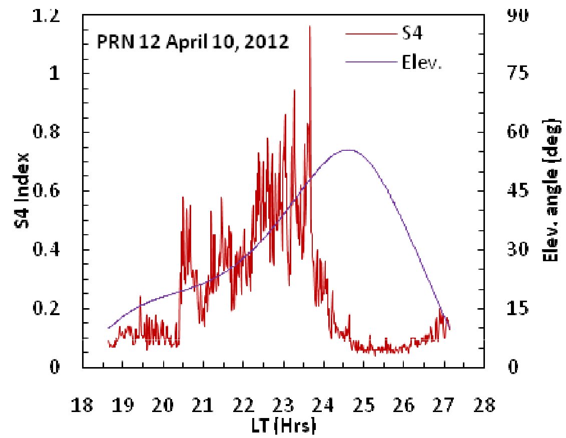
0.4<=S4 > 0.7
(Mod. Scint.)

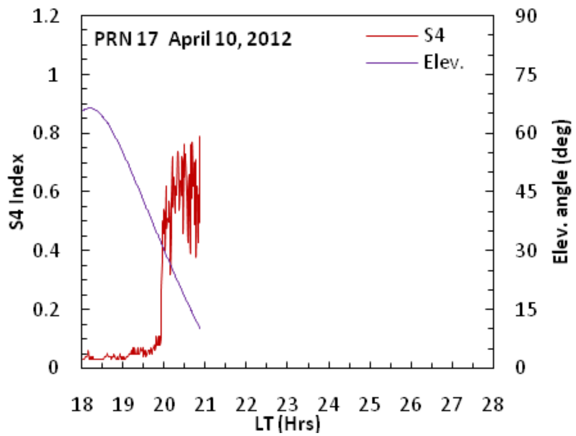
0.3<=S4 > 0.4
(Weak Scint.)

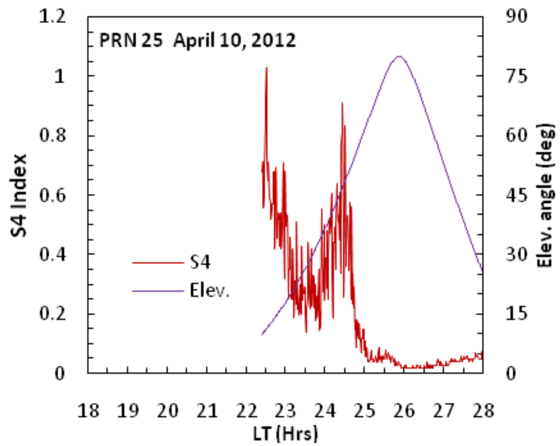
GPS Scintillations over Addis Ababa, 10/04/12

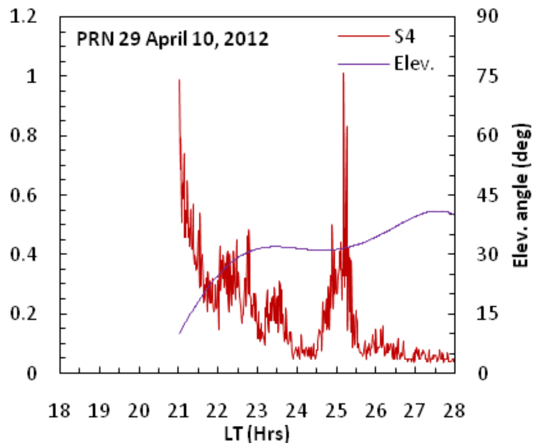




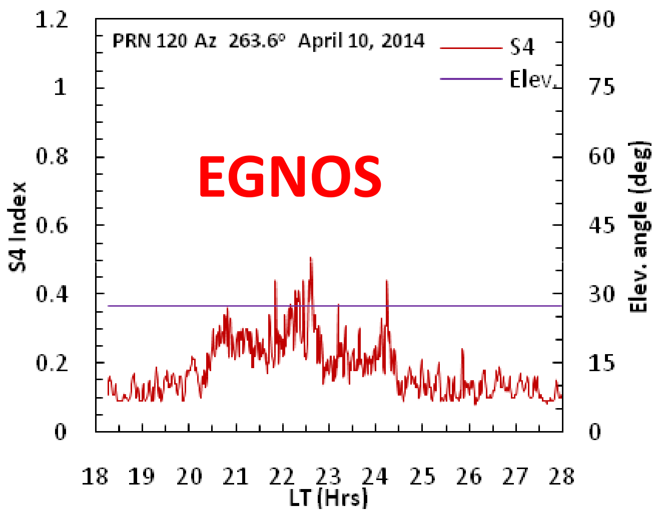


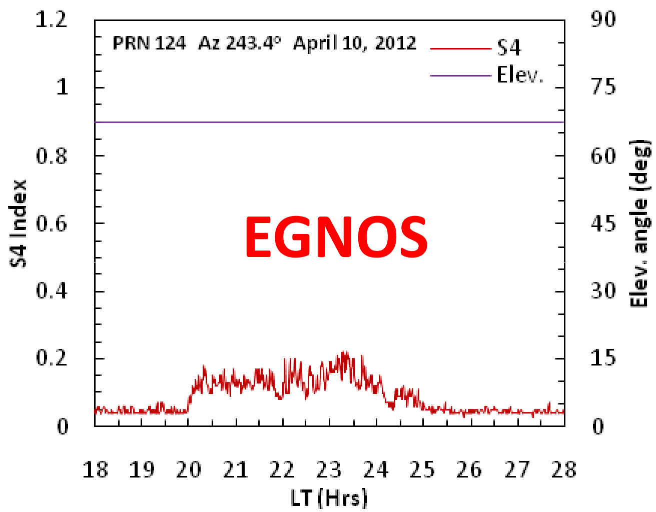




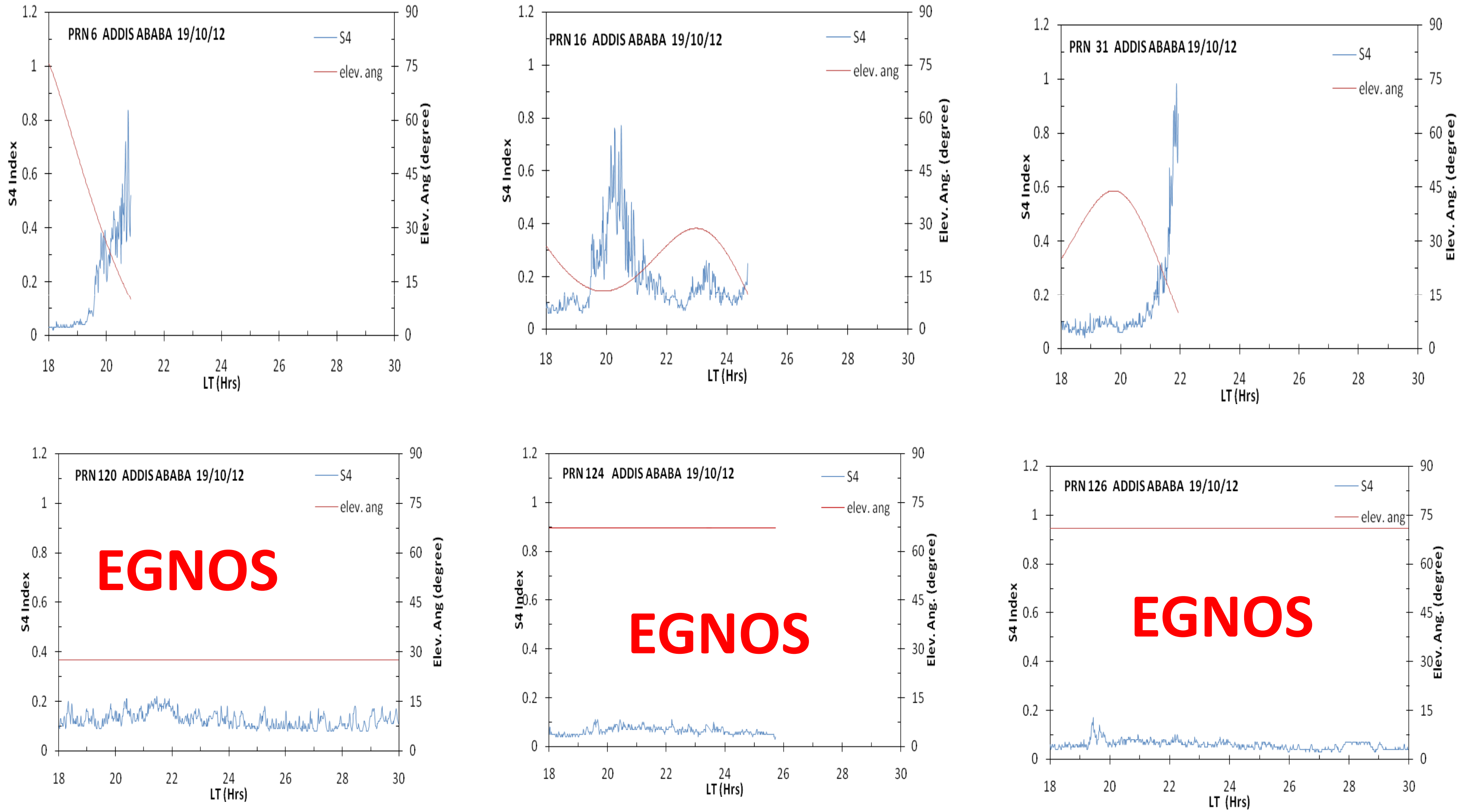


EGNOS Scintillations over Addis Ababa, 10/04/12

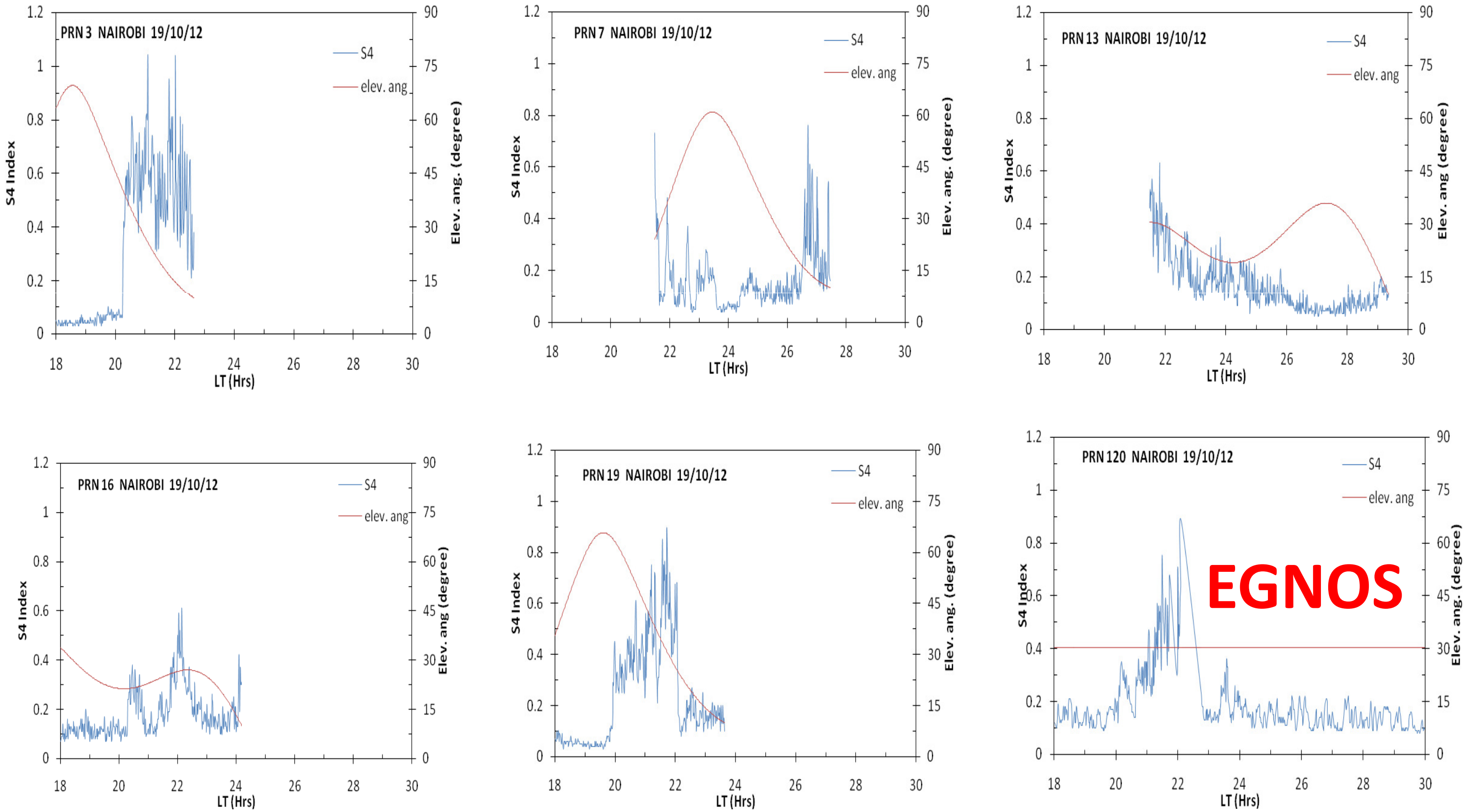




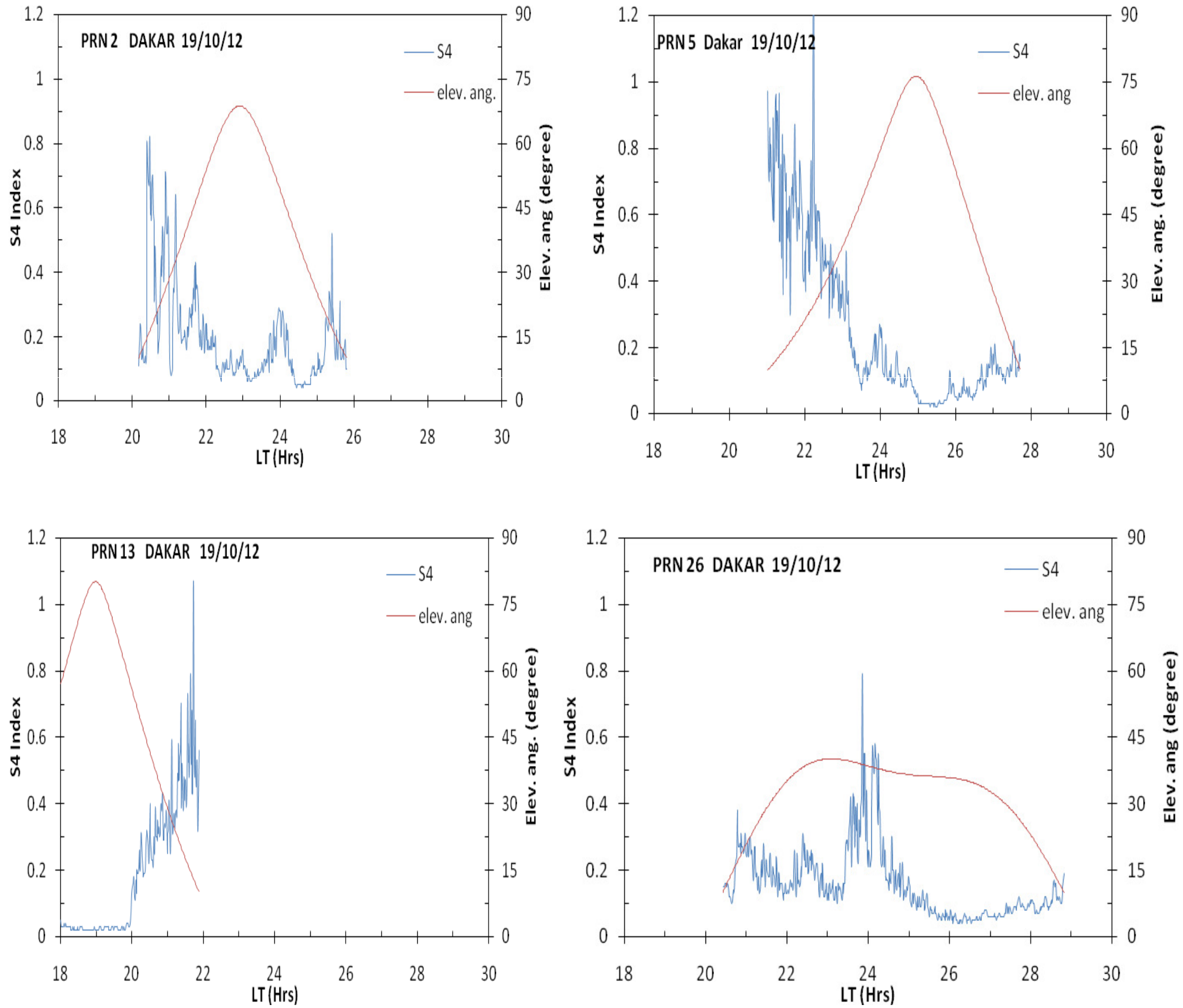
GPS & EGNOS Scintillations over Addis Ababa, 19/10/12



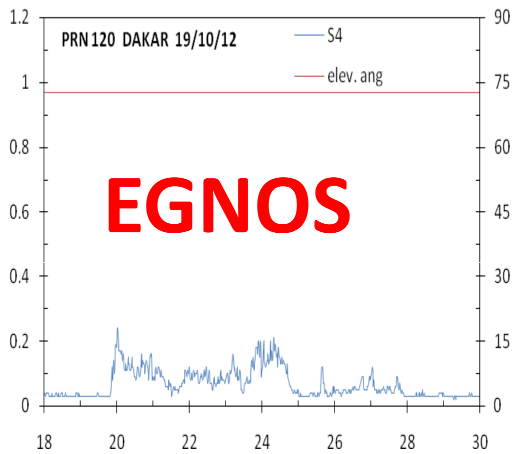
GPS & EGNOS Scintillations over Nairobi, 19/10/12

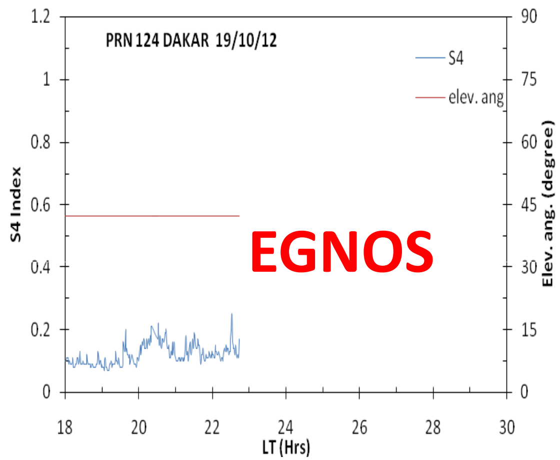


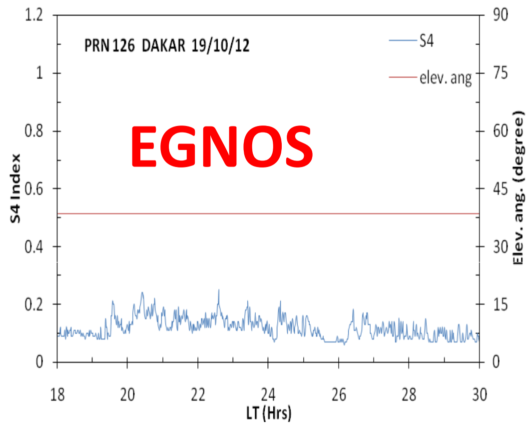
GPS Scintillations over Dakar, 19/10/12



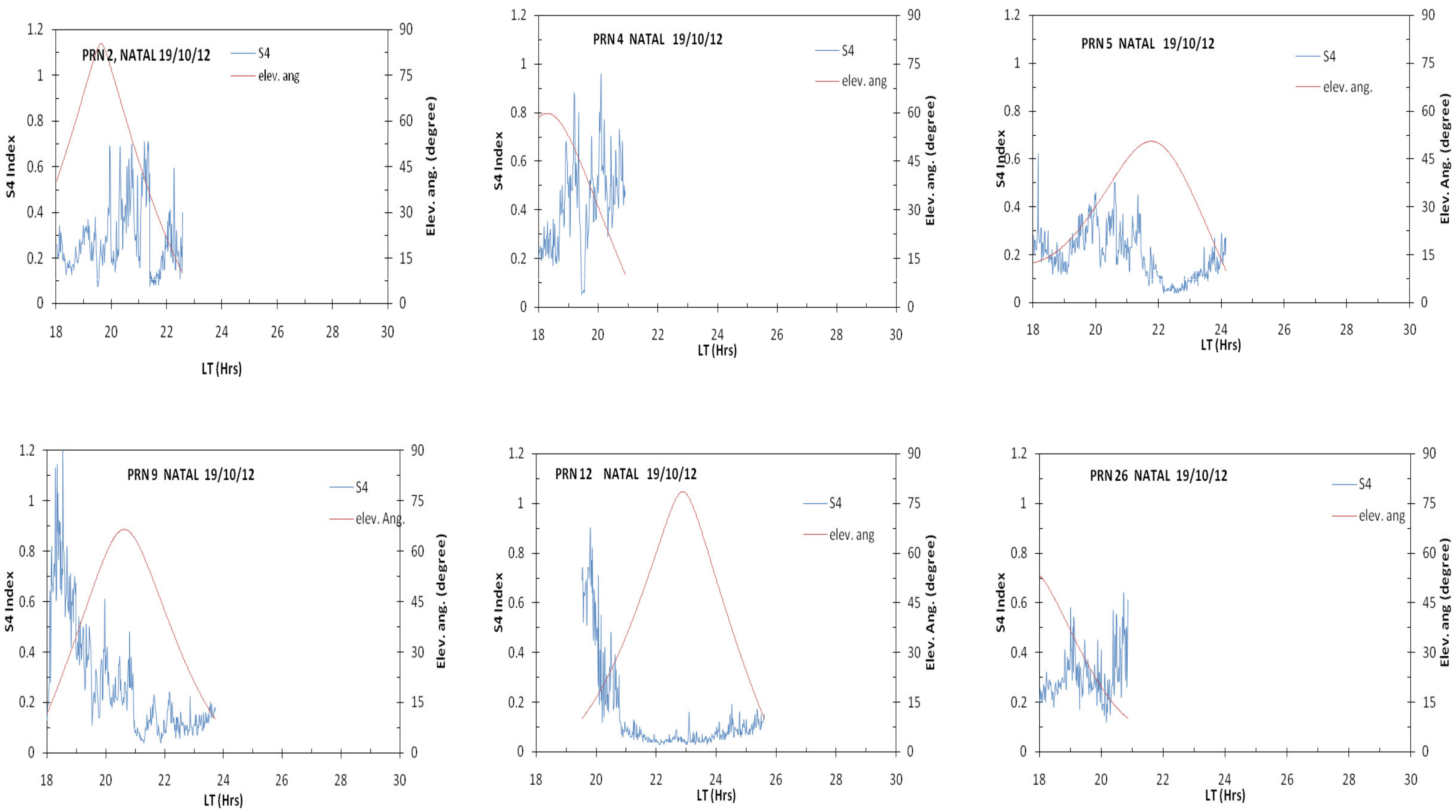
EGNOS Scintillations over Dakar, 19/10/12



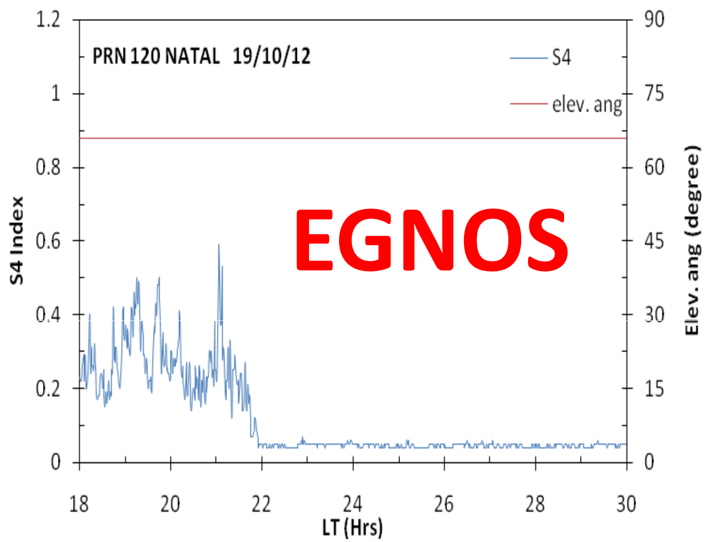


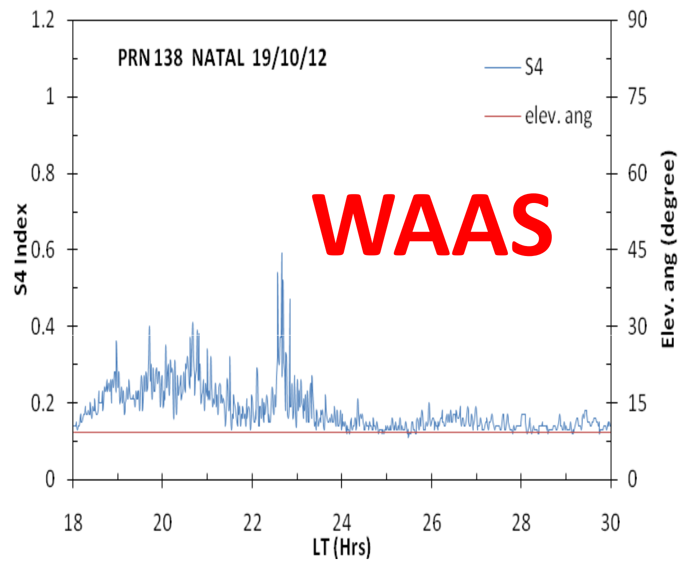


GPS Scintillations over Natal, 19/10/12



SBAS Scintillations over Natal, 19/10/12





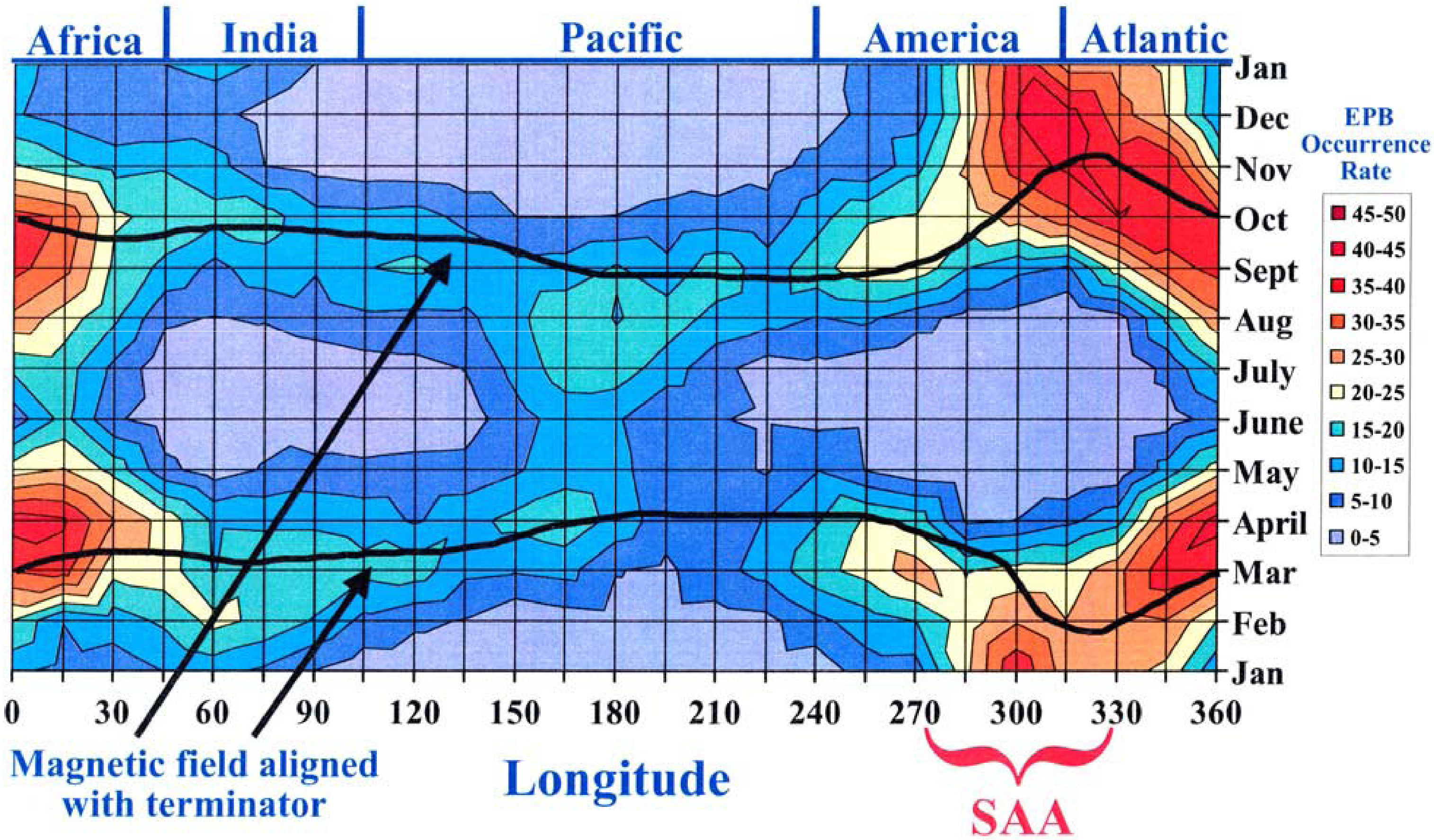
Conclusions

1. Scintillation events recorded the highest daily distribution of occurrences around 22–02 LT.

2. Scintillation occurrences were high during March and September equinox, and low or non-existent during June solstice. Unlike *Akala et al.* [2014; 2015], which reported January as off season for equatorial scintillation occurrences in Africa, significant events were recorded in January at Dakar. We observed that the climatology of GNSS scintillations over Dakar is close to that of South America (Natal).

3. During intense scintillations, SBAS signals are also vulnerable.

Longitudinal variability of equatorial plasma bubbles



Burke et al. (2004), JGR

Proposal for Communication and Navigation Lab

Africans need to work together to address the above state challenges in order to design a robust GNSS technology for the African aviation Industry.

At the University of Lagos, the Communication and Navigation Lab that we are setting up solicits for support/collaborations from ICAO/Allied Agencies and other scientist.

With such collaborations, we can develop a framework for ionospheric data collections, analyses and interpretations for our understanding of the morphology and climatology of scintillations over Africa. Overall, it will lead to developing robust ionospheric scintillation models and GNSS aviation for Africa.

Objectives of the Lab

Manpower development in GNSS technology: Currently, 4 Ph.D, 2 M.Sc, and 2 PGD students are being trained. 4 M.Sc students have been earlier trained. All are Nigerian students, we shall be glad to extend the trainings to other African students. We have expanded our applications of GNSS to include aviation, maritime, and AIT systems.

We hope that the Lab will transform to an Institute in partnership with our University in the future. Or, with the support of UNO, it could be transformed to a Regional Centre for trainings on GNSS for Africa.

Acknowledgements

Boston College and the United State Air Force Research Laboratory (AFRL) for installing GPS receivers across Africa, and the hosting scientists.

International Centre for Theoretical Physics (ICTP), Italy for the Regular Associate Award. Parts of this work were carried out during his last visit (April–May, 2015) to the Centre.

C. Valladares (Boston College); C. Huang (AFRL); S. Saito (ENRI, Japan). UNO/Organizers ICG Expert Meeting for the sponsorship.

Wishing you all, a Merry Xmas and a Prosperous New Year ahead

On the tenth day of Christmas
my true love sent to me:
63 ICG experts are meeting
……………………………………..
and a Partridge in a Pear Tree

Thank You

for your rapt attention!!!

Dr. A. O. Akala

(Communication and Navigation Scientist)

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