IONOSPHERIC SATURATION EFFECT AROUND THE MAGNETIC EQUATOR

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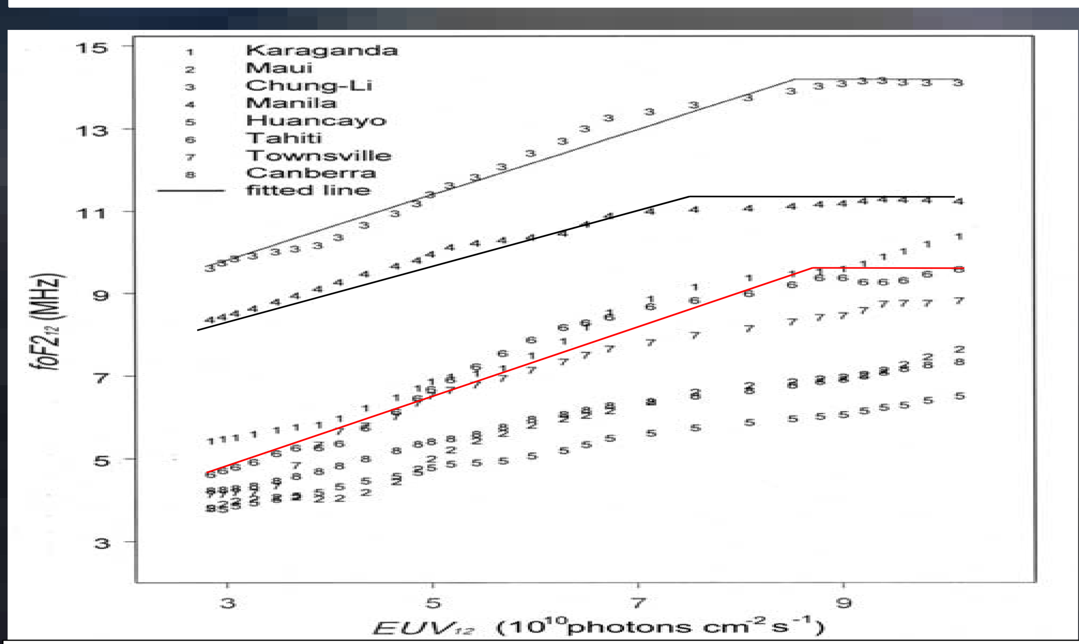
INTRODUCTION

Modeling is an important aspect of ionospheric research. The model of the ionosphere is usually used in setting up of communication link and also for correction purposes in satellite communication. This led the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI) to set up a working group to produce the International Reference Ionosphere (IRI).

One of the factors the ionosphere depends on is the solar activity, which shows the cyclic evolution of solar extreme ultraviolet (EUV) radiation and represented by several proxies such as the sunspot number (Rz), solar radio flux of 10.7 cm wavelength (F10.7), solar activity factor (F10.7P), and so on.

The solar activity dependence of the ionosphere gives to saturation/amplification effects, which is observable at high solar flux levels. Hence the need to study saturation effect, which is stated to have seasonal and latitudinal variations (Ma *et al.*, 2009) with dominance in the equatorial ionization anomaly (EIA) region (Sethi *et al.*,2002; Lui *et al.*,2003; Ma *et al.*,2009). This work is the first of such, investigating the seasonal variation of the saturation effect in the African equatorial ionosphere. However, this work is limited to the trough of the EIA.



Kane (1992) and Balan *et al.* (1993) attributed the saturation phenomenon to nonlinearity between EUV and other solar activity proxies, but Lui *et al.* (2003) also attributed it to ionospheric dynamical processes

Long-term changes in solar activity dependence of foF2 (*Source:* Liu *et al.*, 2003), but modified. [Black line: 3.5ºN (Manila), Blue line: 13.8ºN (Chung-Li), Red line: 15.3ºS (Tahiti)]

DATA AND METHODOLOGY

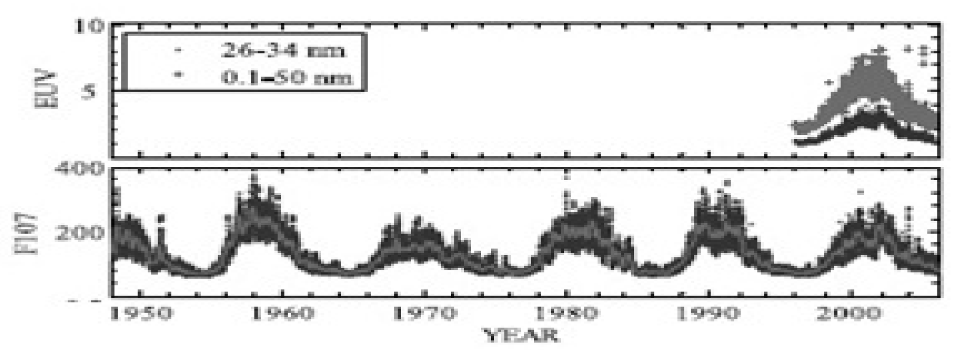
For this work, we use:

Monthly averages of hourly foF2 for Ouagadougou (Geog. 12ºN, 1.8ºW, dip ~3ºN) [1985 – 1995]

and

Monthly averages of F10.7 (sfu)

This is because Ma *et al.* (2009) had shown that F10.7 and F10.7P are better than Rz, and are identical in their relationship with monthly mean of foF2 values obtained from stations around the magnetic equator.
Although, solar EUV is the best solar activity indicator, but not available for the period of study.



Time series of SOHO/SEM EUV fluxes at 0.1 – 50 and 26 – 34 nm wavelength bands and *F10.7* (as well as *F10.7A*, with unit in 10^{-22} W m^{-2} Hz^{-1}) during 1996–2005 (Source: Lui *et al.* 2006)

The months were classified into seasons as:
March Equinox (February, March, April); September Equinox (Aug., Sept., October)
June solstice (May, June, July); December Solstice (November, December, January)

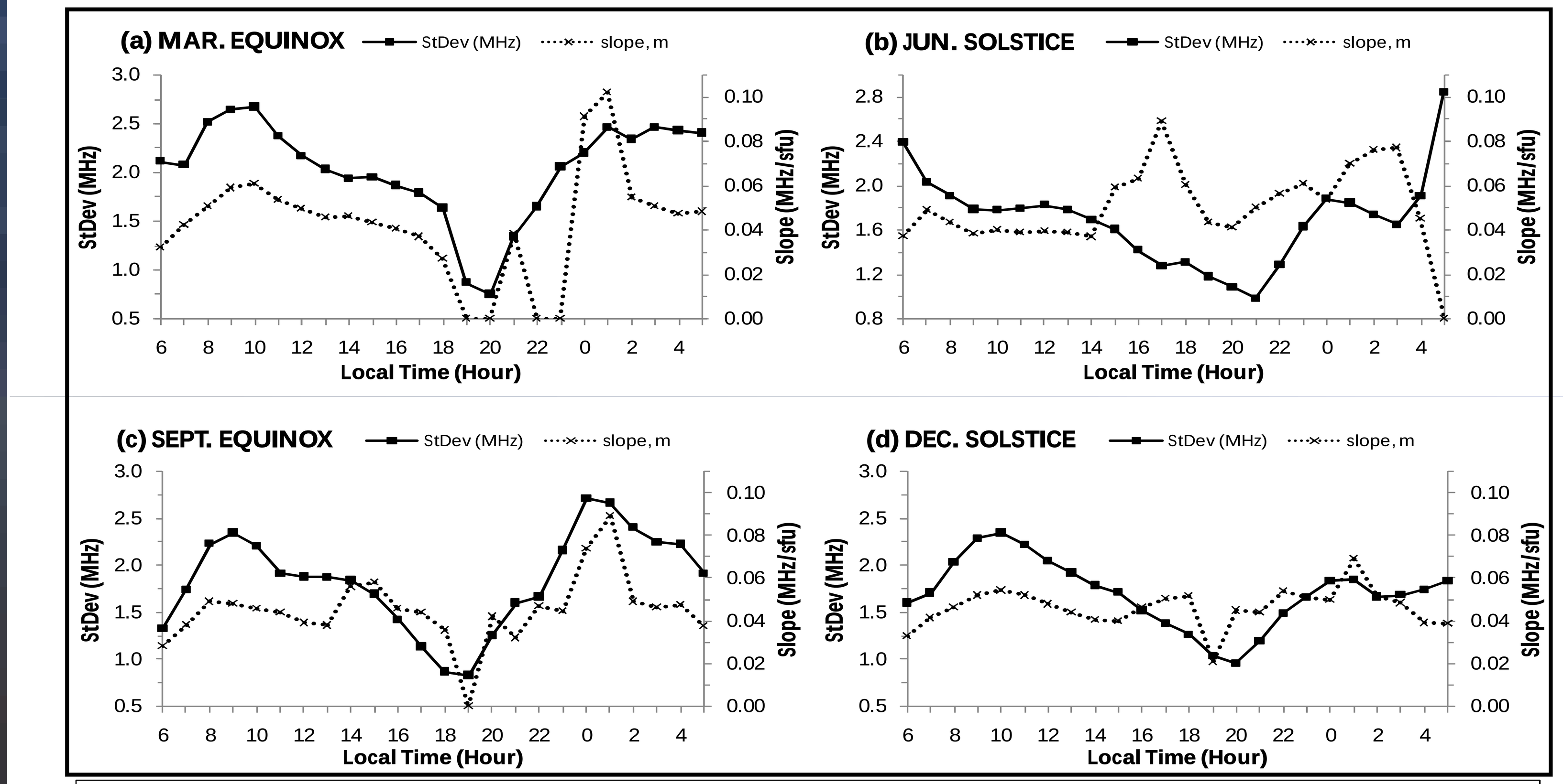
RESULTS

Analysis of the seasonal observations at Ouagadougou

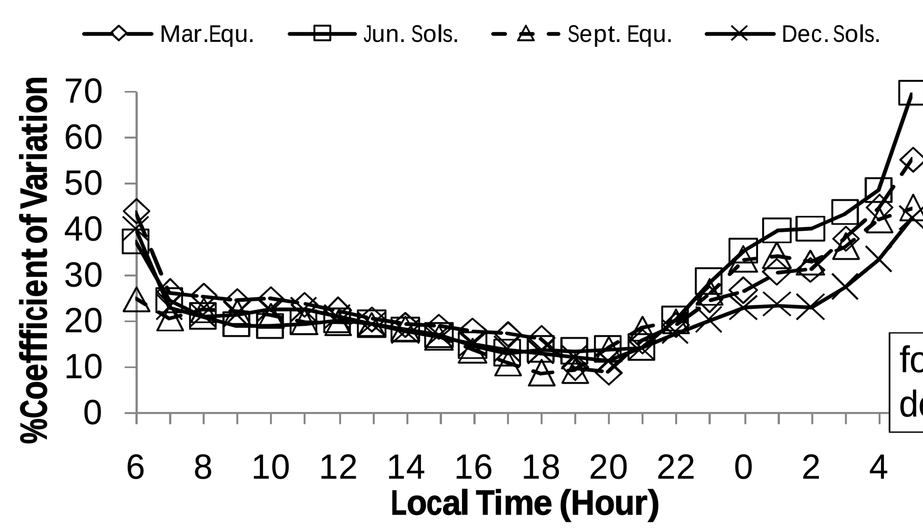
The goodness of fit F-value and the F10.7 breakpoints for each season

	MARCH EQUINOX		JUNE SOLSTICE		SEPTEMBER EQUINOX		DECEMBER SOLSTICE	
LT (HR)	*F* value	$F10.7_{BP}$ (sfu)	*F* value	$F10.7_{BP}$ (sfu)	*F* value	$F10.7_{BP}$ (sfu)	*F* value	$F10.7_{BP}$ (sfu)
0	9.696*	119.52	3.134	146.08	5.214	144.60	7.683*	152.30
1	6.685*	119.52	2.069	126.00	2.771	130.50	10.983*	131.14
2	3.947	155.53	3.597	124.40	2.443	171.20	10.275*	144.18
3	0.283	172.69	6.783*	119.40	3.268	180.54	8.445*	149.06
4	0.464	188.12	2.964	169.50	5.069	180.54	1.978	171.87
5	1.596	188.12		171.13**	3.238	186.80	0.199	173.50
6					8.115*	183.67	1.842	171.87
7	1.150	188.12	0.481	179.48	9.540*	180.50	5.848*	157.21
8	4.673	188.12	1.453	177.81	6.718*	175.90	6.940*	168.61
9	9.691*	172.69	0.797	172.80	5.542	177.40	7.313*	171.87
10	9.061*	170.97	1.551	164.40	6.413*	177.40	10.550*	171.87
11	8.118*	170.97	1.020	171.13	5.034	166.50	10.388*	171.87
12	7.153*	170.97	0.804	167.79	5.443	179.00	7.667*	171.87
13	6.196*	170.97	2.643	172.80	4.185	177.40	9.690*	171.87
14	5.938*	164.11	1.880	167.79	4.046	138.30	7.794*	171.87
15	3.493	164.11	3.112	126.00	4.683	130.50	7.701*	168.61
16	2.918	160.68	5.435	117.69	4.824	135.20	8.719*	145.81
17	1.805	157.30	3.065	117.70	6.941*	125.80	10.715*	131.14
18		169.25***		114.35***	3.306	110.16	6.841*	123.00
19		143.53**		124.37***		94.52**	0.091	168.60
20		86.94**	5.390*	114.30	1.387	118.00	6.979*	116.50
21	4.214	129.81	10.962*	109.30	1.079	138.30	4.884	127.90
22		86.94**	7.268*	121.03	2.373	132.10	8.237*	131.10
23		86.94**	6.078*	125.57	4.720	194.62	17.662*	144.20

* 0.01 *significance level* ** *No 90% confidence block*
*** *90% confidence block extends beyond the data range*



Variations of the standard deviation of foF2 with the slope, m, of the first segment of the two-segmented fits. (a)March equinox, (b)June solstice, (c)September equinox (d) December solstice.



foF2 variability (% ratio of the standard deviation) or all seasons.

- Saturation effect in foF2 is more pronounced during daytime for all seasons, except in June solstice.
- Daytime saturation effect in foF2 is closely related to low variability, except in June solstice.
- There is high likelihood that will foF2 saturate at high solar flux levels irrespective of the time during December solstice.
- Saturation effect in foF2 exhibits some seasonal variations.

RESULTS (cont'd): Comparison with other studies

- Saturation effect across all seasons in low-latitude at midday (Sethi *et al.*, 2002; Xu *et al.*, 2008).
- Saturation higher at noon than pre-noon and post-noon periods around the EIA crest (Lui *et al.* 2003)
- It is significant/substantial at the PRE peak period in the EIA crest (Lui *et al.* 2003)
- Saturation effect at midday is higher in winter and equinoxes than summer (Sethi *et al.* 2002) .
- Midnight saturation effect in summer at the outer edge of the northern EIA crest (Xu *et al.*, 2008)
- Saturation at mid-latitude, except winter (Sethi *et al.*, 2002), Amplification effect at high and mid-latitudes in winter (Ma *et al.*, 2009)
- Weaker in the trough than the crest of the EIA. Seasonal variation less pronounced in the EIA compared with the high and mid-latitude regions (Ma *et al.*, 2009).
- Saturation features deviates greatly from IRI representation at low-latitude but agreed well at mid-latitude.

Around the African magnetic equator:
- Observations agree
- Saturation lower at noon than pre/post-noon periods around the EIA trough
- Not significant at the PRE peak period
- Midday effect is highest in December Solstice, and lowest in the June Solstice.
- Midnight saturation effect highest in December solstice and lowest in June solstice
- Saturation effect dominates. No amplification feature.

CONCLUSION

- Saturation features dominates the trough of the EIA ionosphere at high solar activity irrespective of the season.
- Ionospheric foF2 saturation effect exhibits midnight semiannual variation and daytime annual asymmetry.
- Besides the ionization of neutral specie, ionospheric saturation effect is greatly influenced by electrodynamics in the EIA region such as the vertical plasma drift and thermospheric circulation.
- With respect to the comparison with other works, seasonal variation in ionospheric saturation effect is more observable beyond the equatorial region.
- Inclusion of the latitudinal and seasonal variations of the saturation effect in the IRI could help improve its performance, especially for sunspot maxima.

FUTURE WORKS

- Validating the observation for the African EIA trough with larger volume of data (with say data covering two or more sunspot cycles)
- Investigate the exact contribution of the several ionospheric electrodynamics in the observed saturation effect n the African equatorial region

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