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GROUPE: GEOMAGNETISME ET AERONOMIE

STUDY OF IONOSPHERIC SCINTILLATIONS AND TEC CHARACTERISTICS AT SOLAR MINIMUM IN A WEST AFRICAN EQUATORIAL REGION USING GPS DATA

United Nations/Japan Workshop on Space Weather; Fukuoka, Japan, 2-6 March 2015

OUTLINE

1. BACKGROUND
2. THE STATION LOCATION AND COORDINATES
3. DATA USED
4. METHOD OF ANALYSIS
5. RESULTS
   - THE RESULTS FOR S4 INDEX
     - S4 DIURNAL VARIATION
     - S4 SEASONAL VARIATION
     - S4 ANNUAL VARIATION
   - THE RESULTS FOR TEC
     - vTEC DIURNAL VARIATION
     - vTEC SEASONAL VARIATION
     - vTEC ANNUAL VARIATION
6. CONCLUSION AND FURTHER WORK

United Nations/Japan Workshop on Space Weather
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1. BACKGROUND

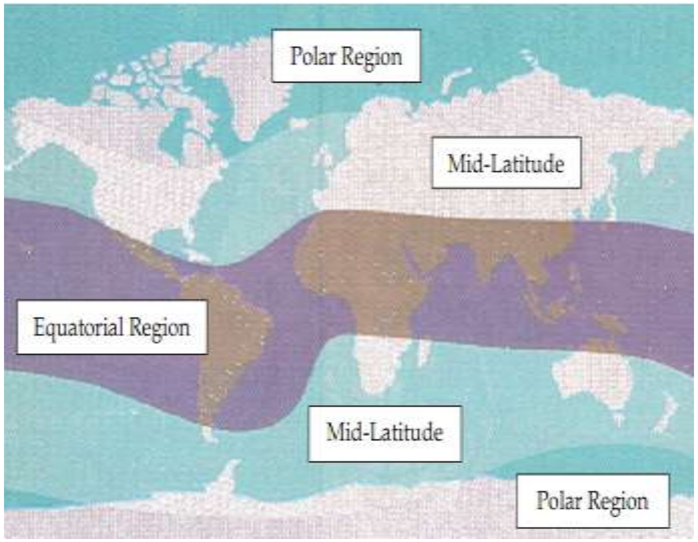

Fig 1: Equatorial region scintillation belt (www.vs.afrl.af.mil)

SCINDA Africa Network Existing Sites

1.Sal, Cape Verde.
Mr. Jose Pimenta Lima

2.Abidjan, Ivory Coast.
Pr. Olivier Obrou

3.Akure, Nigeria.
Dr. Babatunde Rabiu

4.Lagos, Nigeria.
Dr. Larry Amaeshi

5. Addis Ababa, Ethiopia.
Dr Gizaw Mengistu

6.Bahir Dar, Ethiopia.
Dr. Baylie Damtie

7.Nairobi, Kenya
Dr. Paul Baki

- ● Pre-2006 SCINDA Sites
- ● Existing IHY Sites
- ● Planned IHY Sites 2008
- ● Potential IHY Sites 2009

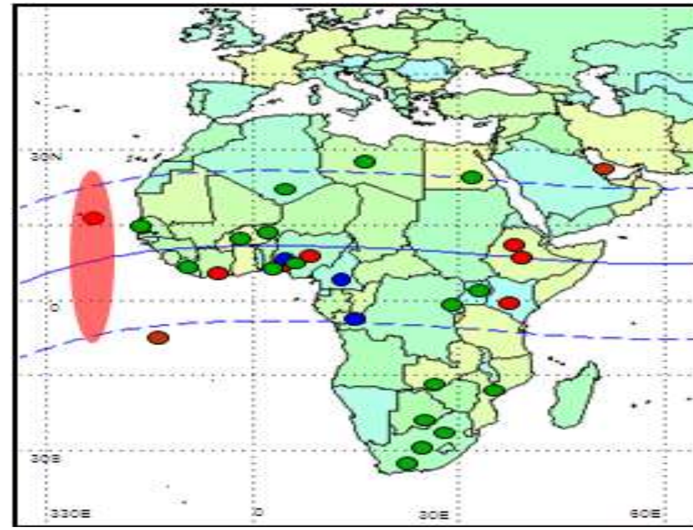

Fig 2: SCINDA AFRICA Network Existing Sites, Source: Keith Groves

- SCINDA is the Scintillation Network Decision Aid developed by the Air Force Research Laboratory’s (AFRL’s). It aims to predict satellite communication outage.
- SCINDA advises operational users in real-time when and where scintillation is likely to occur.
- Ionospheric scintillations are rapid variations in the amplitude and phase of trans-ionospheric radio signal due to turbulence generated by ionospheric irregularities.

2. THE STATION LOCATION COORDINATES

Fig 3: An overview of the GPS Data Acquisition System
Latitude = 5.3440 N, Longitude = 3.9004 W

3. DATA USED

- Period of study

We used data from Abidjan station GPS receiver. This study covers the period from January 2008 to January 2009: a minimum solar activity as:

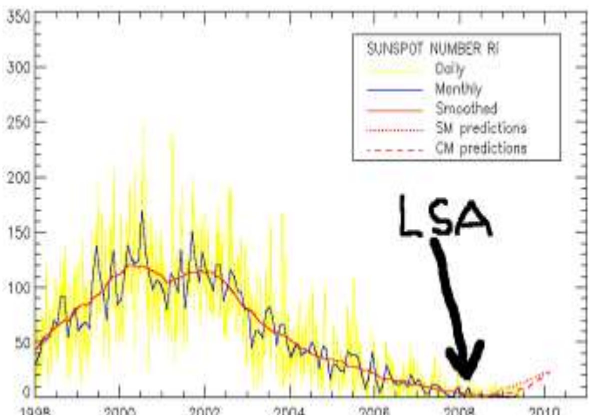

Fig 4: Sun spot number variation from 1998 to 2010. (Source: http://www.sidc.be, June 1, 2009)

- SCINDA data files

We are *.scn, *.psn, *.msg, *.nvd, *.ism files extension in zip compressed format. For studying, we used ionospheric statistics file *.scn which needed unzip

Below is an excerpt from a sample *.scn file showing ionospheric statistics for the eleven satellites with

#YYMM		DD	UTSEC	AZ	EL	PLAT	PLON	PCGLAT	PCMLT	S4	DPR	PTEC	STEC	STECE	VTEC	VTECE	PRN
09	01	01	00098	194.30	30.10	0.69	-5.17	-6.35	-0.76	0.05	12.49	0.00	-1.00	-1.00	-1.00	-1.00	02
09	01	01	00098	159.20	11.10	-4.41	-0.29	-11.29	-0.50	0.14	12.04	0.00	-1.00	-1.00	-1.00	-1.00	04
09	01	01	00098	268.50	24.50	5.16	-9.90	-3.30	-1.01	0.12	21.69	0.00	16.69	80.44	8.44	40.70	09
09	01	01	00098	359.00	79.90	5.88	-4.00	-3.15	-0.64	0.04	11.58	0.00	9.51	80.44	9.37	79.32	10
09	01	01	00098	208.80	16.00	-1.96	-7.99	-8.07	-0.98	0.23	26.19	0.00	-1.00	-1.00	-1.00	-1.00	12
09	01	01	00098	333.70	18.90	11.93	-7.31	0.12	-0.80	0.21	14.86	0.00	-1.00	-1.00	-1.00	-1.00	15
09	01	01	00098	111.30	16.20	2.31	3.70	-5.92	-0.18	0.22	13.59	0.00	-1.00	-1.00	-1.00	-1.00	17
09	01	01	00098	280.70	19.40	6.64	-11.12	-2.49	-1.07	0.10	12.57	0.00	-1.00	-1.00	-1.00	-1.00	24
09	01	01	00098	355.00	26.10	10.87	-4.48	-0.45	-0.63	0.12	16.63	0.00	11.73	80.38	6.16	42.18	26
09	01	01	00098	44.50	31.20	8.63	-0.71	-1.69	-0.42	0.10	9.18	0.00	11.14	80.46	6.52	47.09	28
09	01	01	00098	246.00	75.20	5.02	-4.71	-3.61	-0.69	0.03	-41.07	0.00	-1.00	-1.00	-1.00	-1.00	120
09	01	01	00158	193.90	29.90	0.65	-5.15	-6.39	-0.75	0.08	12.59	0.00	-1.00	-1.00	-1.00	-1.00	02
09	01	01	00158	158.90	10.80	-4.54	-0.18	-11.43	-0.48	0.26	-7.56	0.00	-1.00	-1.00	-1.00	-1.00	04
09	01	01	00158	269.00	24.50	5.21	-9.90	-3.27	-0.99	0.11	23.69	0.00	16.45	80.44	8.32	40.70	09
09	01	01	00158	359.40	80.40	5.85	-3.99	-3.17	-0.63	0.03	9.58	0.00	9.45	80.44	9.34	79.42	10
09	01	01	00158	208.90	16.40	-1.83	-7.93	-7.97	-0.95	0.37	29.09	0.00	-1.00	-1.00	-1.00	-1.00	12
09	01	01	00158	334.10	19.10	11.90	-7.24	0.11	-0.77	0.16	16.26	0.00	-1.00	-1.00	-1.00	-1.00	15
09	01	01	00158	110.80	16.30	2.39	3.70	-5.86	-0.16	0.17	5.49	0.00	-1.00	-1.00	-1.00	-1.00	17
09	01	01	00158	280.30	19.50	6.58	-11.09	-2.52	-1.05	0.08	14.17	0.00	-1.00	-1.00	-1.00	-1.00	24
09	01	01	00158	355.50	26.20	10.86	-4.43	-0.46	-0.62	0.12	21.83	0.00	11.72	80.38	6.16	42.27	26
09	01	01	00158	44.20	30.80	8.70	-0.68	-1.66	-0.40	0.09	11.48	0.00	11.12	80.46	6.45	46.71	28
09	01	01	00158	246.00	75.20	5.02	-4.71	-3.61	-0.68	0.03	-41.07	0.00	-1.00	-1.00	-1.00	-1.00	120
09	01	01	00218	193.50	29.60	0.59	-5.13	-6.43	-0.73	0.11	14.99	0.00	-1.00	-1.00	-1.00	-1.00	02
09	01	01	00218	158.60	10.60	-4.61	-0.10	-11.51	-0.46	0.18	10.44	0.00	-1.00	-1.00	-1.00	-1.00	04
09	01	01	00218	269.50	24.60	5.27	-9.88	-3.24	-0.98	0.15	21.09	0.00	16.32	80.44	8.27	40.79	09
09	01	01	00218	359.70	80.90	5.82	-3.99	-3.18	-0.61	0.04	9.68	0.00	9.40	80.44	9.30	79.53	10
09	01	01	00218	208.90	16.80	-1.70	-7.87	-7.88	-0.93	0.29	26.09	0.00	-1.00	-1.00	-1.00	-1.00	12
09	01	01	00218	334.40	19.30	11.86	-7.18	0.08	-0.75	0.12	14.06	0.00	-1.00	-1.00	-1.00	-1.00	15
09	01	01	00218	110.30	16.30	2.45	3.72	-5.81	-0.14	0.15	4.29	0.00	-1.00	-1.00	-1.00	-1.00	17
09	01	01	00218	279.80	19.50	6.52	-11.11	-2.55	-1.04	0.08	12.47	0.00	-1.00	-1.00	-1.00	-1.00	24
09	01	01	00218	355.90	26.40	10.82	-4.39	-0.48	-0.60	0.11	25.63	0.00	11.75	80.38	6.20	42.46	26
09	01	01	00218	43.90	30.50	8.75	-0.67	-1.63	-0.38	0.10	8.08	0.00	11.11	80.46	6.41	46.42	28
09	01	01	00218	246.00	75.20	5.02	-4.71	-3.61	-0.66	0.03	-41.07	0.00	-1.00	-1.00	-1.00	-1.00	120

- Scintillation Index S4

The scintillation is quantified by means of an index, defined as:

$$S4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}}$$

where I is the signal intensity.

- Total Electron Content

TEC is the number of electrons in a tube of 1m^2 cross section extending from the receiver (R) to the satellite (S) defined as:

$$TEC = \int_S^R n_e(l)\,dl$$

where n_e (l) is the electron density along the signal path.

4. METHOD OF ANALYSIS

❖ Only the portion of the signal that travels along the direct path from the satellite is useful. All other contributions are called multipath.

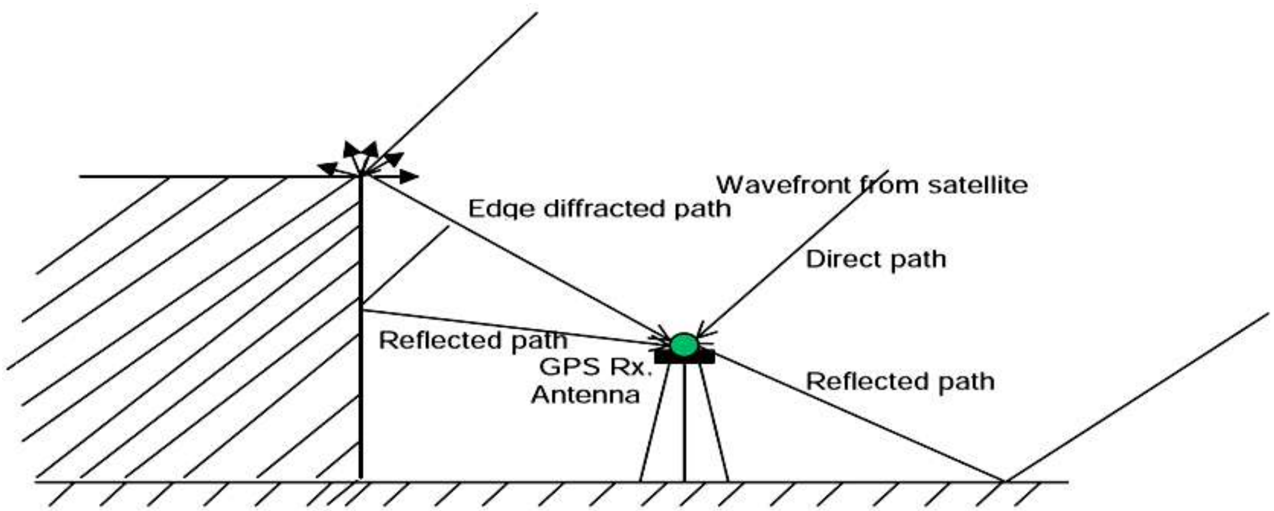

Fig 5: Typical multipath scenario (Rao, 2006)

❖ Signal interference at the antenna due to multipath causes fluctuations that can resemble scintillation, but these fluctuations are not caused by the ionosphere

❖Multipaths were cut off following the criteria of Otsuka et al., (2006). It's non significant if the elevation angle EL > 30° .

❖TEC were calibrated using the technique by Carrano et al, (2009).

5. RESULTS

❑ S4 INDEX DIURNAL VARIATION

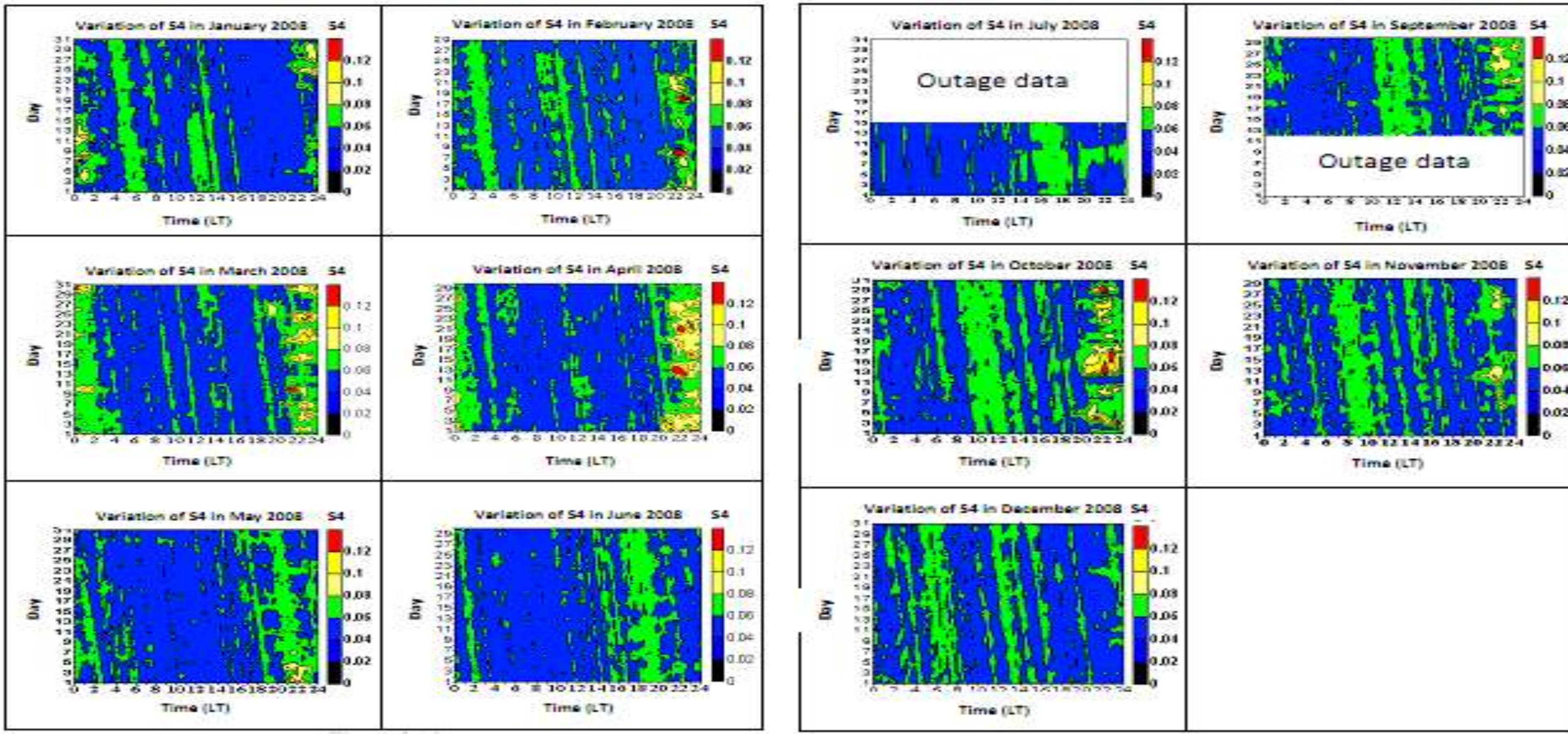

Fig 6: S4 index diurnal variation on January, February, March, April, May, June, July, September, October, November and December 2008.

5. RESULTS

❑ S4 INDEX SEASONAL VARIATION

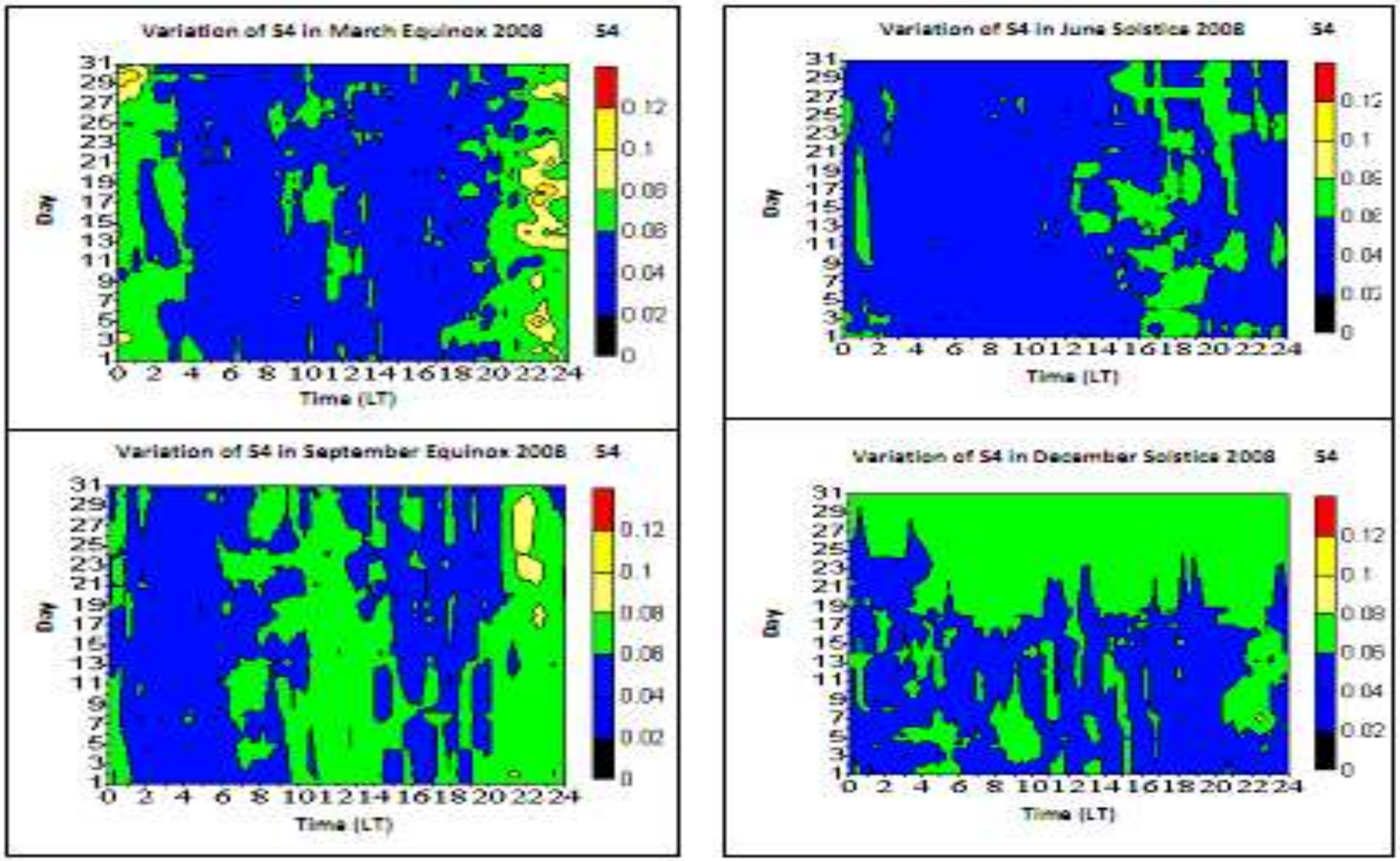

Fig 7: S4 index seasonal variation on March Equinox, September Equinox, June Solstice and December Solstice 2008

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5. RESULTS

❑ S4 INDEX ANNUAL VARIATION

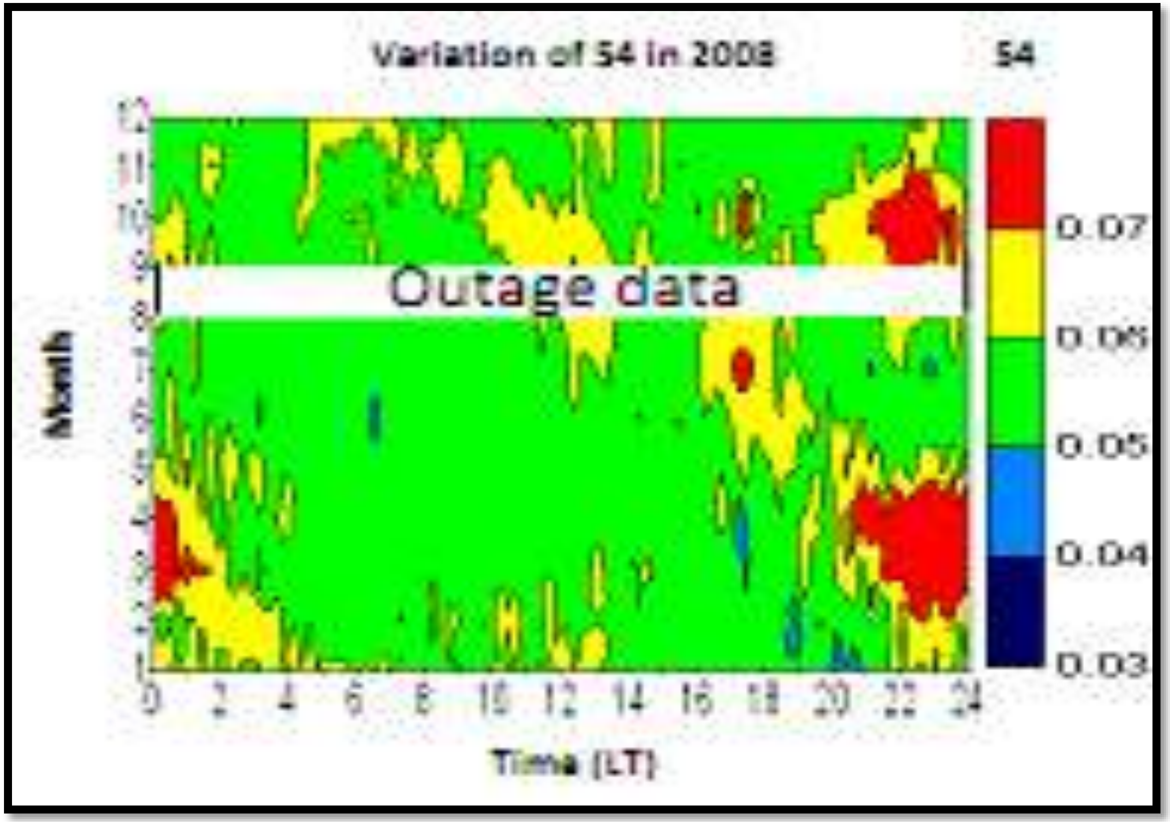

Fig 8: S4 index annual variation in 2008

5. RESULTS

❑ vertical TEC (vTEC) DIURNAL VARIATION

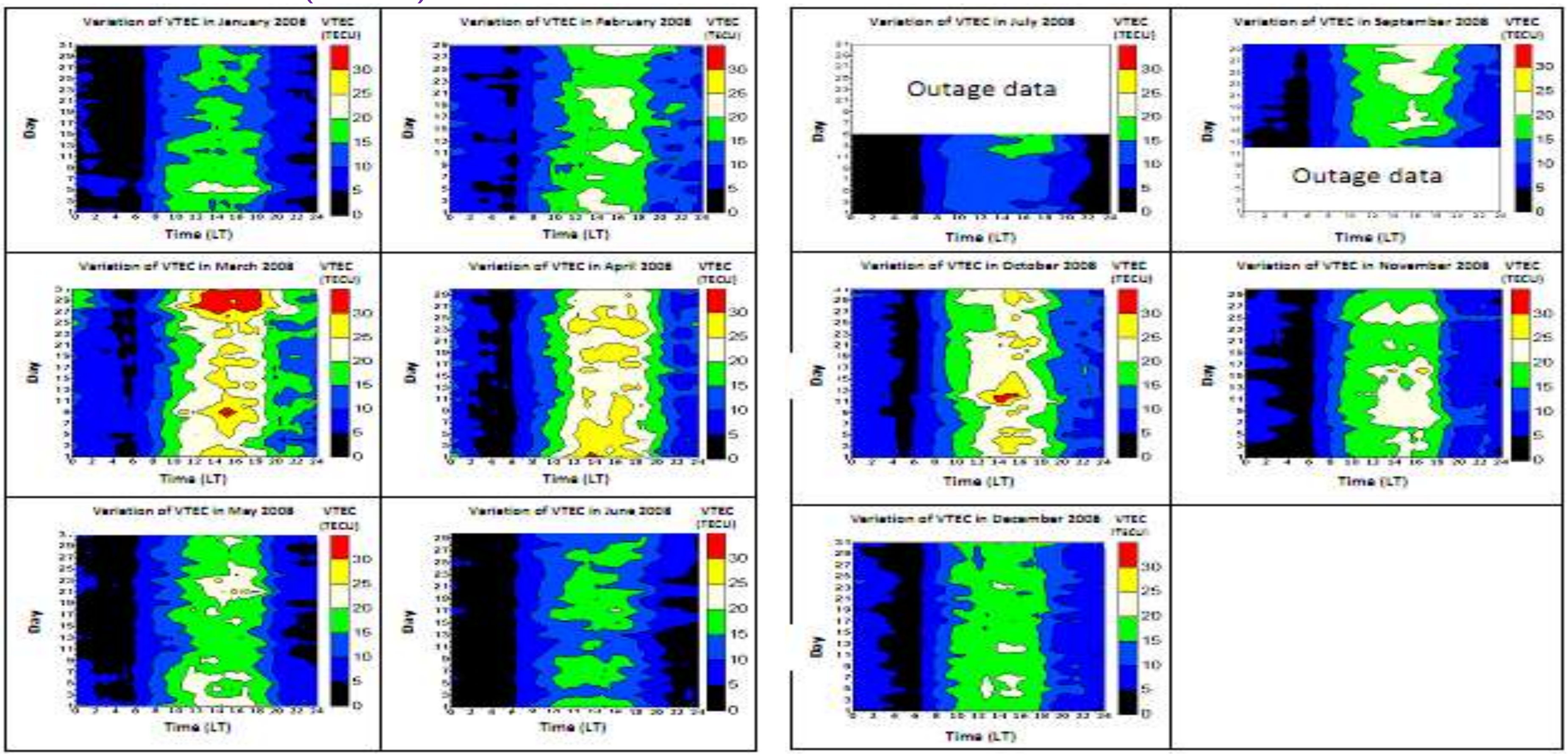

Fig 9: vTEC diurnal variation on January, February, March, April, May, June, July, September, October, November and December 2008

5. RESULTS

❑ vertical TEC (vTEC) SEASONAL VARIATION

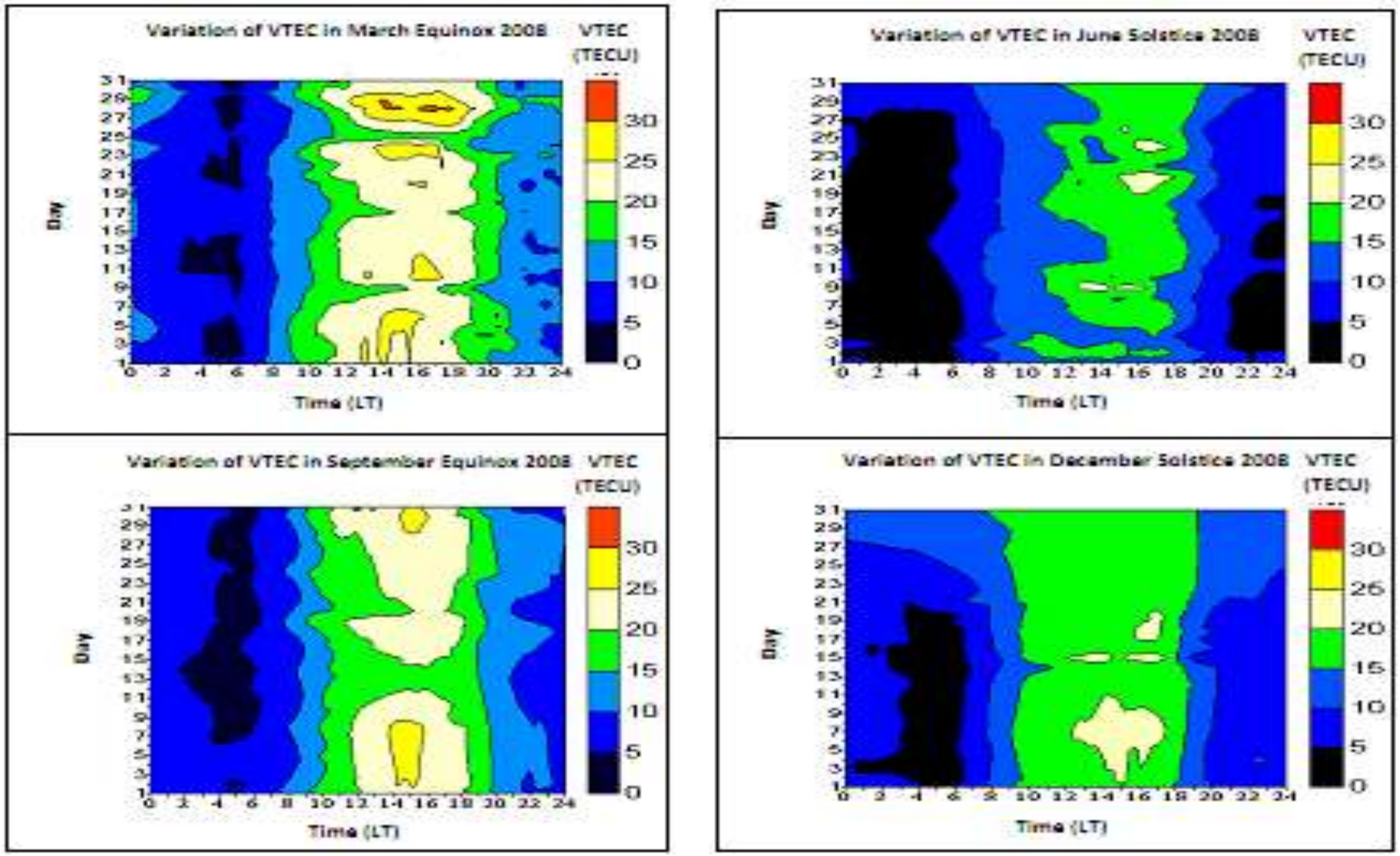

Fig 10: vTEC seasonal variation on March Equinox, September Equinox, June Solstice and December Solstice 2008

United Nations/Japan Workshop on Space Weather
‘’Science and Data Products from ISWI Instruments’’
Fukuoka, Japan, 2-6 March 2015

5. RESULTS

- vertical TEC (vTEC) ANNUAL VARIATION

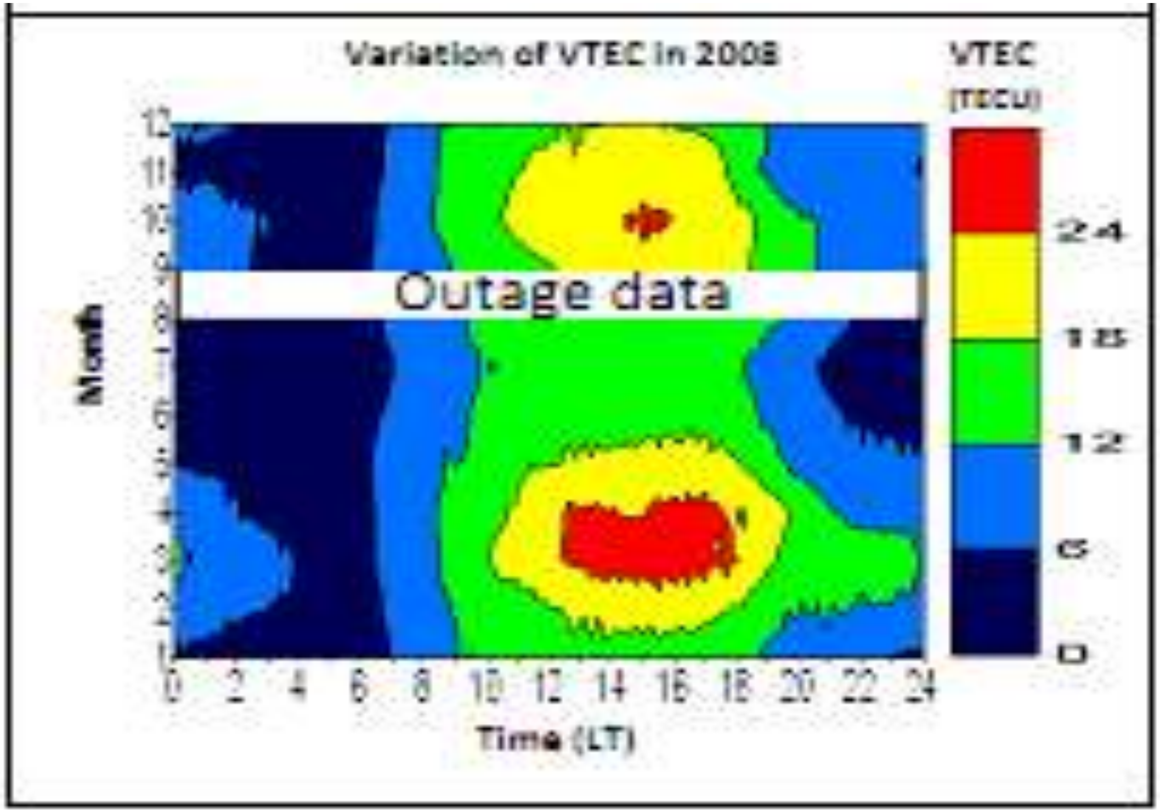

Fig 11: vTEC index annual variation in 2008

5. RESULTS

In this study, our observational results show that:

- GPS scintillations occurred between 20:00 to 00:00 and extend to 02:00 in some cases where the greatest average value of scintillation index S4 is equal to 0.14.

- Largest values of TEC appear from 11:00 to 19:00 where the maximum average value is equal to 35 TECU.

- The scintillation is thus approximately a nighttime effect (Knight and Finn, 1996; Visessiri et al., 2003; Boutiouta et al., 2006) while TEC is sensitive to daytime hours.

- According to Abdullah et al. (2009), scintillation activity indicated by S4 has four categories i.e. $S4 \leq 0.25$ is quiet, $S4 > 0.25$ and $S4 \leq 0.5$ is moderate, $S4 > 0.5$ and $S4 \leq 1$ is disturbed, then $S4 > 1$ is severe. Therefore, we obtain a low scintillation activity and TEC values in this minimum solar activity period.

- Our observational results show also equinoctial asymmetry in both the scintillation index S4 and the TEC, which were reported in previous studies (Wiens et al., 2003; Visessiri et al., 2003; Otsuka et al., 2006).

6. CONCLUSION AND FURTHER WORK

The results of ionospheric scintillations and TEC at solar minimum at Abidjan show that:

- The scintillation is approximately a nighttime ionospheric effect while the TEC is sensitive to daytime hours.
- Scintillation and TEC exhibit very low values at solar minimum and near magnetic equator.
- S4 and TEC show a seasonal effect that is prominent during the equinoctial.

As a future plan, we suggest to:

- ✓ Compare our results to another SCINDA data or RineX data in the region + or – 10° latitude.
- ✓ Work on data covering high solar activity epoch to clearly confirm the solar activity dependence of the scintillation phenomenon in an equatorial region
- ✓ Study the effects of ionospheric scintillation on satellite-earth communications near magnetic equator.
- ✓ Study the impacts of geomagnetism storm on TEC in an equatorial region.

Université de Cocody - Abidjan

THANKS FOR YOUR ATTENTION DURING THIS PRESENTATION