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Day-To-Day Variability in Some Ionospheric Parameters in the Quiet Equatorial Ionosphere

Case Study: Ionospheric Critical Frequency Of The E-Region, $F_o e$

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Abstract-- Day-to-Day Variability is some ionospheric parameters in the quiet equatorial ionosphere, case study: f_oE is hereby presented. The diurnal variation curve of f_oE showed a symmetrical one with a peak value at noon. The seasonal variation curve of the f_oE has two maximum points in the months of April and August. It is also shown that for short time variation, the day-to-day variability in the E-region of the ionospheric critical frequency, f_oE is not due to season nor relative sunspot number Rz. The test of significance carried out between the standard errors of f_oE before and after correction showed no significant difference at 95% level of significance.

I. INTRODUCTION

The ionospheric behavior of the earth's upper atmosphere during quiet time is of vital importance in trans-ionospheric communication. This is owing to the fact that the local time, season, solar cycle and longitude play a significant role in varying the ionosphere as a result of charges in the components of solar radiation and other dynamic and chemical processes (Richards, 2001; Sardar, Singh, Nagar, Mishra and Vijay, 2012). The seasonal behavior of the ionosphere has been explored with measurement of critical frequency, peak electron density of the f_2 layer and total electron content (Mc Namara and Smith, 1982; Sardar et al, 2012). Also the day-to-day changes in the F region critical frequency were closely related on an average of day-to-day changes in the noon values of Sq (rate of electron production) at the magnetic equator. (Ratcliffe and Bates et al, 1960). They attributed this correspondence to day-to-day differences in the dynamo electrostatic field generated by winds near or within the E-region. There is little information about the E-region of the ionosphere because at night the critical frequency f_oE lies outside the working range of most ionosonde. It has been shown that at night f_oE varies so much from hour to hour and from night to night; that it is impossible to describe a regular behaviour (Yokoyama, 2004). This variability is probably evidence that at night the phenomenon of Es, is particularly noticeable.

Regardless of the improved knowledge of the ionospheric dynamics, the day-to-day variability from one day to the next at a given hour, hour-to-hour variability: from one hour to the next at the same day, and within-the-hour variability: that occurs within a single hour, still lies within the framework of statistical estimations and the underlying physical mechanisms are far from being fully understood. Also, no enough records of f_oE at night as a result of slow decay of ionization produced during the day by photo-ionization and due to slow recombination process. Thus the study of the variability of the ionosphere parameters is a very important means of studying the variation of the equatorial ionosphere. Practical implications of space weather studies include knowledge of impact of ionospheric variability on trans-ionospheric radio propagation (Zhang, Shi, Wang and Radicella, 2004) and on space based communication and navigation system as well as for modeling the ionosphere has contributed to space weather study and investigation of existing prediction model of the ionosphere.

II. DATA COLLECTION

The data used in this study are hourly f_oE values onbtained from ionosonde recorded into booklets located at University of Ibadan, Oyo State Nigeria in the year 1972

IBADAN

Geographic Coordinates	07^0 24'N	03^0 54'E
Geomagnetic coordinates	$+10.6^0$	74.6^0
Magnetic dip	-6^0	
Time Meridian	0^0	

III. EQUIPMENT DETAILS

Frequency range 0.67Mc/S - 25Mc/sS in fine bands

Band 1	0.67-1.4Mc/S	0-1 minutes after start
Band 2	1.4-3.1Mc/S	1-2 minutes after start
Band 3	3.1 – 6.9Mc/S	2-3 minutes after start
Band 4	6.9-15.4Mc/S	3-4 minutes after start
Band 5	15.4-25Mc/S	4-5 minutes after start

Sweep time:	5 Minutes
Peak power:	1 kw approx.
Pulse reputation rate:	50p.p.s
Pulse length:	80μs to 330 μs, normally 100 μs
Aerial in use:	Vertical rhombic

Recordings, normally every hour, are made on 70mm photographic paper and the time reference is that when the sounder sweep starts.

IV. TERMINOLOGIES USED

Daytime:	Hours between 0600 and 1800hrs
Night time:	Hours between 1900 and 0500hrs
f_0E:	Ordinary-wave critical frequency

conforms with that recommended in the U.R.S.I handbook of Ionogram Interpretation and Reduction", Edited by W.R Piggott and K.Rawer (1961)

Season: The Months of March and April represents March equinox, with May and August representing June Solstice (Bilitza et al, 2004)

V. ANALYSIS/RESULTS/DISCUSSION

f_0E daytime variation (Diurnal variation) table 1 and 2 are observed values of f_0E at each hour of the day for which observations were made.

Table 1: March Equinox (Month of April) f_0E Values (Observed) MHz

QD	06	07	08	09	10	11	12	13	14	15	16	17	18	Rz
8	2.10	3.05	3.60	4.00	4.30	4.30	-	-	4.20	3.95	3.60	2.85	1.70	246
9	2.30	3.10	-	4.10	-	4.35	4.50	-	4.20	-	-	-	-	204
10	2.20	3.05	3.65	4.05	4.40	-	-	-	-	-	-	-	-	197
11	2.10	3.10	3.60	3.90	4.30	4.30	-	-	-	-	-	2.80	1.60	159
12	2.10	3.05	3.10	4.05	4.15	4.30	4.40	4.30	4.10	3.75	3.40	-	1.80	140
13	2.10	3.05	-	4.00	4.20	4.35	4.35	4.30	4.05	3.80	-	2.65	1.60	127
22	2.30	3.20	3.65	4.00	-	4.30	-	4.30	-	-	3.40	-	-	212
23	2.30	3.35	3.75	4.08	4.29	4.33	4.39	4.33	4.19	4.00	3.76	3.30	2.57	201

Table 2: June Soltice (Month of June) f_0E Values (Observed) MHz

QD	06	07	08	09	10	11	12	13	14	15	16	17	18	Rz
3	2.50	3.20	3.2	4.00	4.15	4.30	4.30	4.20	-	3.30	2.85	2.85	1.80	181
4	2.50	3.20	0	4.10	4.40	4.40	4.45	-	-	4.05	4.35	2.80	1.90	195
5	2.45	3.30	3.70	4.00	4.30	4.45	4.40	4.35	4.15	3.80	3.35	2.95	1.85	195
13	2.25	3.15	3.65	3.65	4.20	4.20	4.20	4.25	4.15	4.00	3.85	3.40	2.90	176
16	2.30	3.15	3.65	4.00	4.20	4.30	4.30	4.30	4.00	3.75	3.30	2.70	1.80	100
17	-	-	3.80	-	4.20	4.35	4.50	4.20	4.00	4.00	3.45	2.95	1.90	113
18	2.20	3.10	3.35	3.85	-	4.25	4.25	-	3.90	3.60	3.35	2.70	1.80	100
20	2.20	3.20	3.65	3.95	4.15	-	-	-	3.95	3.65	3.30	2.80	1.80	107

The day time variation curves are as shown in figure 1 below

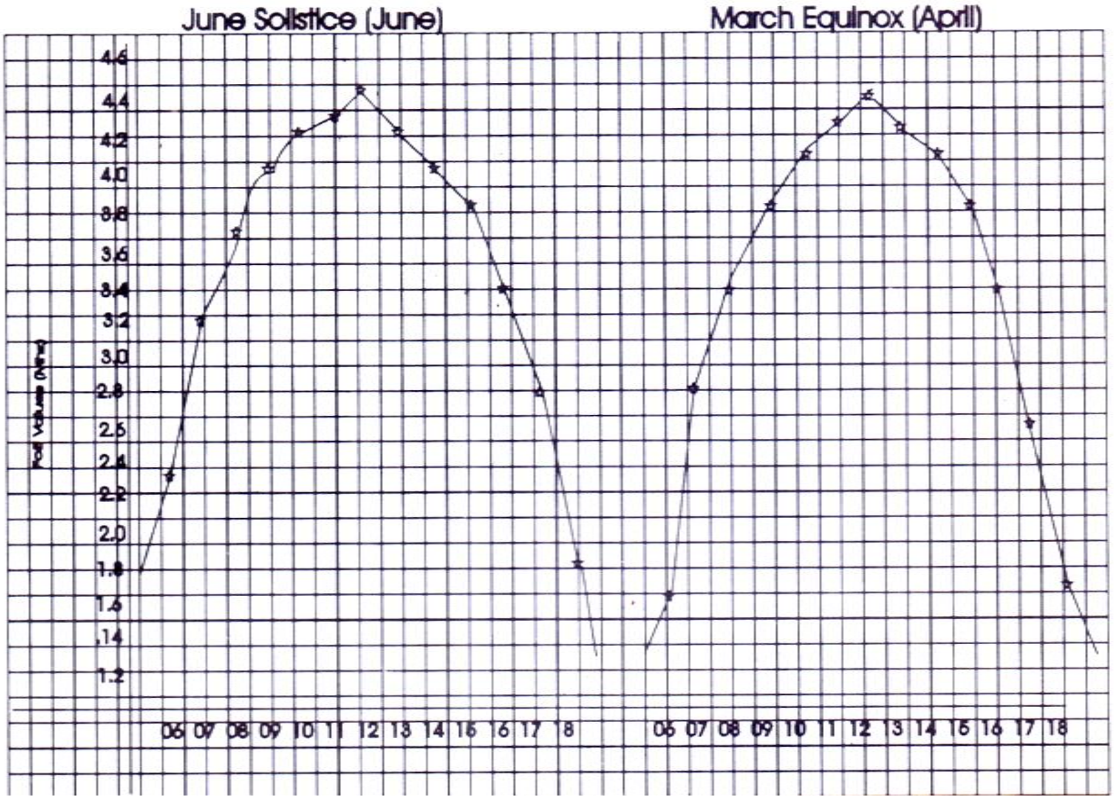

Figure 1: Time in Hours

The curves show a symmetrical one with peak value at noon. It is important at this point, to mention that from the diurnal variation curve of f_oE, the recombination coefficient $\propto$ can be determined from

$Dt = \frac{1}{2\propto N_0}$ (Appleton, 1959)

Where Dt is the delay between noon and the time of maximum N_m, and N_0 is the noon value (Since $N_m \propto f_oE^2$)

However, it is necessary to identify and measure any departures from the normal behaviour; so as to estimate any significant difference between the standard errors in the diurnal variation curves before and after correction. Based on the later, the following seasons are represented by the months that belong to the season and the standard errors determined at some chosen hours of the day.

Month of April (March Equinox)

Month of June (June Solstice)

For example: March Equinox

At 0700hrs

Mean f_oE = 3.10MHz

Standard derivation = 0.05

Standard error = 0.02

Hence $f_oE = (3.10 \pm 0.02)$MHz

Similar analysis was carried out at various times of the day

A. f_oE Seasonal Variations

Table 3 shows the mean values of f_oE by the month for the year under consideration

Table 3

Months	f_oE(MHz)
January	4.35
February	4.31
March	4.40
April	4.41
May	4.33
June	4.36
July	4.35
August	4.46
September	4.42
October	4.38
November	4.28
December	4.24

The above table was used to plot the seasonal variation curve shown in figure 2 below

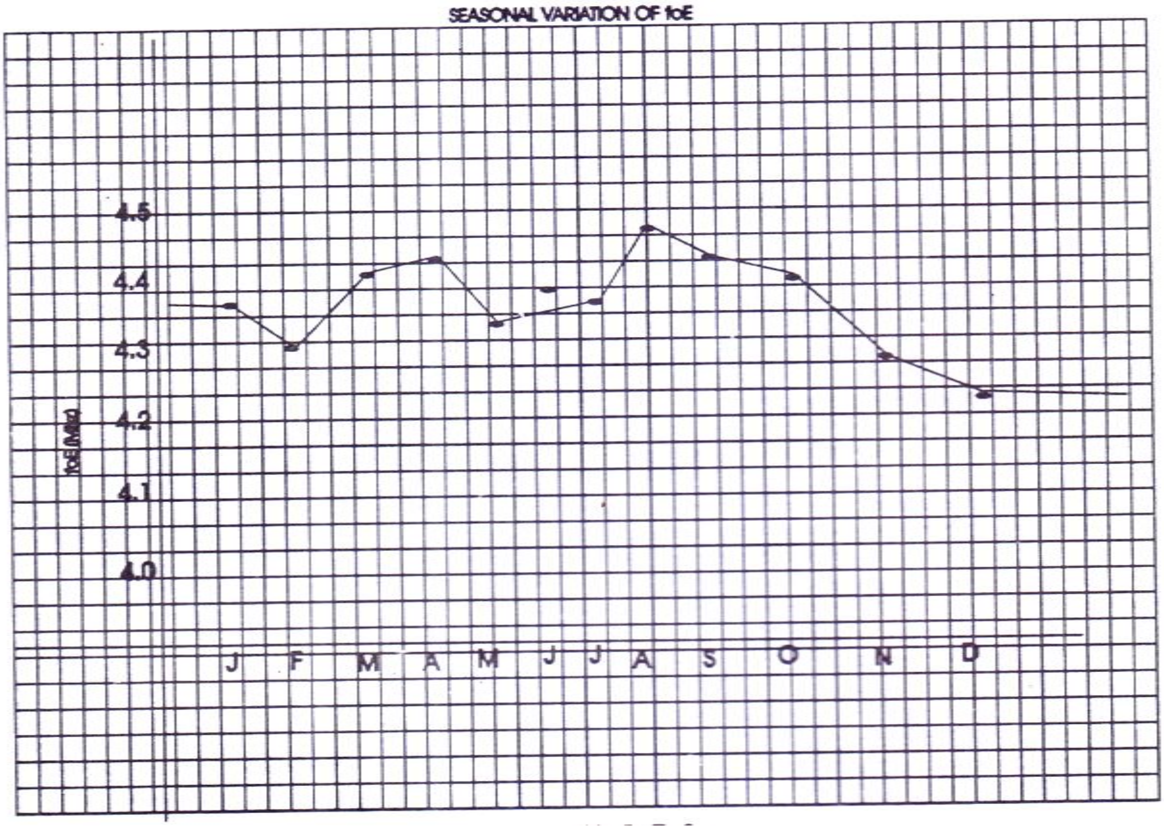

Figure 2: Months

The curve has two maximum points in the months of April and August. It is necessary to observe that the concentration of oxygen in the E layer is largest in summer. Also the E layer is influenced by drift, solar tide motion as well as layer distortion.

B. Effect of season and sunspot number Rz on the critical frequency of the E layer

It is essential to examine the effect of the Rz and season on f_0E. Based on the latter, the seasonal variation curve, fig. 2 above was used to correct for season. Lynon (1964) found that variation of noon time f_oE at Ibadan with sunspot number Rz was given by

$$f_oE = 3.47\,(1 + 0.0014Rz)$$

The above equation was used to correct for Rz. The corrected diurnal variation curves are as shown in fig 3 for the solstice and equinox

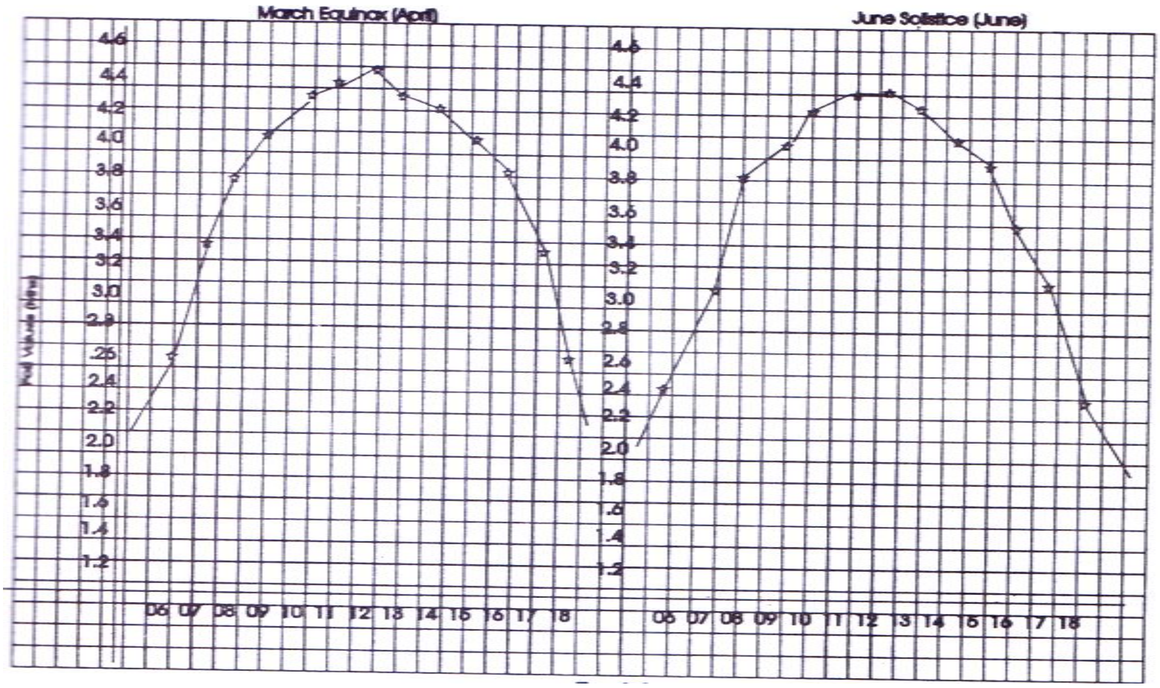

Figure 3: Time in Hours

From the corrected f_oE curves, the standard errors were obtained as shown in the example below

a. March equinox (Month of April) at 0700hrs

Mean f_oE = 2.61MHz
If d = derivation from the mean

n = number of observations
then,
standard deviation $\sigma_m = \frac{\sigma}{\sqrt{n}} = 0.8MHz$
similar analysis was carried out at various times of the day Table 4 below shows the result obtained

Table 4 March Equinox (April)

Time	07	09	12	14	16	18
σ	0.25	0.08	0.06	0.09	0.30	0.89
σ_m	0.08	0.02	0.03	0.04	0.15	0.44
$3\sigma_m$	0.24	0.06	0.09	0.12	0.45	1.32

C. June Solstice (June)

Time	07	09	12	14	16	18
σ	0.12	0.10	0.07	0.09	0.18	0.48
σ_m	0.04	0.03	0.02	0.03	0.06	0.02
$3\sigma_m$	0.12	0.09	0.06	0.09	0.18	0.48

D. Test of significance for diurnal variation

A statistical test was carried out to test the significance between the standard errors of the variation curves of f_0E before and after correcting for season and Rz at 95% level of significance. The results obtained are as shown

1. Month of April (daytime) 1200hrs
   Before = 0.03
   After = 0.03
   t 95% = 2.31
   t = 0
   t 95% > t (t = 0)
2. Month of June (Daytime)
   Before = 0.03
   After = 0.03
   t 95% = 2.31
   t = 0.16

Hence, no significant difference at 95% level. These results above show that the day-to-day variation in the E-region of the ionosphere is neither due to seasonal variation nor relative sunspot number Rz

VI. DISCUSSION

The normal behaviour of the E-layer of the ionosphere obtained in this study agrees with that developed by Chapman (1960) in the classical theory of ionized layer formation. The seasonal variation of f_0E has two maximum points in the months of April and August. The test of significance carried out shows that the day-to-day variability in the E-region of the ionosphere is neither due to season nor relative sunspot number Rz. This is in agreement with Chou and Lee (2008)

CONCLUSION

In the E-region, dynamo electrostatic fields are generated by winds. It could therefore be said that changes in some parameters such as ionospheric diffusion, wind as well as electrodynamics drift-vertical or horizontal could be responsible for the day-to-day variability in that region. Other causes could be solar tides and layer distortions. It is therefore suggested that these variables be investigated for the disturbed E layer so that the result established be proposed as equatorial input values for the development of a variability model for the international ionosphere.

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