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Day - to - Day Variability of the Critical Frequency of F1 (foF1) Layer

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Abstract

The characterization of the day – to – day variability (VR) of the critical frequency of F1 (foF1) layer on diurnal and seasonal scale is undertaken at Ibadan (7.4°N, 3.9°E, 6°S dip) in the African sector during low solar activity (LSA) and moderate solar activity (MSA). The latitudinal effect on foF1 VR is also investigated by combining data from Singapore (1.3°N, 103.8°E, 17.6°S dip) in the East Asian sector and Slough (51.5°N, 359.4°E, 66.5°N dip) in the European sector. The variability of foF1 is found to be of order (1-3.8%) during LSA and (2-9%) during MSA. On the seasonal scale foF1 VR is greater during March Equinox for both epochs. Comparison of foF1 VR with foE VR and foF2 VR shows that foF1 VR is of the same order of magnitude (0.5 to 4%) during LSA and slightly greater than foE VR (1.5 - 6%) during MSA, in general. It is less than foF2 VR (2 – 15%) during both epochs. Daytime (10:00 h -16:00 h) foF1 VR is greater at Singapore (1.8 – 5.8%) and at Ibadan (1.8 – 5.8%) than at Slough (2.2 – 4.0%), on a general note. While pre-sunrise and post-sunset peaks are apparent at Slough, they are not at Singapore and Ibadan.

Keywords

foF1 Variability, Solar Activity, F1 Layer, Latitude

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1. Introduction

Day – to – day variability is the most random of all ionospheric variations [18]. The subject of space weather of which variations in the ionosphere is major, has great impact on trans – ionospheric radio communication and navigation systems [20], [7], [6]. Being bounded below by the neutral atmosphere and above by the magnetosphere, the ionosphere is a strategic part of the atmosphere. "[5]" has pointed out the need to study variabilty i.e deviations from climatological means of ionospheric characteristics. Of all the layers in the ionosphere the least studied is the F1 layer. The F1 layer of the ionosphere lies at an altitude of approximately 140–210 km. The ionized component of the F1 layer consist mostly of NO^+ and O_2^+ as primary, and O^+, N^+ as secondary positive charge carriers. The main source of ionization is extreme ultraviolet (EUV) solar radiation in the wavelengths $\lambda \approx 58.4$ and 30.4 nm. The height of F1 varies with solar activity, season, and geomagnetic activity. Rocket experiments have revealed a maximum density height hmF1 from 160 to 180 km, while ionograms from ionosonde measurements indicate ≈200 km. Like the E layer, the F1 layer is a Chapman layer with maximum electron density reaching about 2×10^{11} el/m^3 at midday. It exhibits dependence on solar zenith angle χ and sunspot number Rz. Accordingly, the F1 layer is more pronounced in summer than in winter, always disappears

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during the night and sometimes in winter even during the day. Under those conditions the F1 and F2 layers form a single portion of the ionospheric F region.

[1]" mentioned that studies on equatorial F1 region are generally much less than those of F2 region. The reason, perhaps, is because it is not present throughout the day and it is most pronounced in summer and at the minimum of solar cycle [10].

The aim of this study is to characterise the variability of the critical frequency of F1 layer (foF1), on diurnal, seasonal and solar cycle scales. The study also hopes to augment the data used for the modelling of foF1 variability of the ionosphere by International Reference Ionosphere (IRI) [6].

2. Data and Method

The data used in this study are the daily foF1 hourly values of Ibadan (7.4°N, 3.9°E, 6°S dip) Singapore (1.3°N, 103.8°E, 17.6°S dip) and Slough (51.5°N, 359.4°E, 66.5°N dip). They were obtained by the Union Radio mark II Recorder type ionosonde at these stations. "[12]" has described the ionosonde at Ibadan in details. The critical frequency of F1 layer, foF1 during low solar activity (LSA) year (1965, Rz = 16.8), moderate solar activity (MSA) year (1973, Rz = 30.2) are used for the Ibadan station. High solar activity (HSA) foF1 data at Ibadan are scanty except at summer solstice and so are not considered. This is because foF1 values are more readily available in the neighbourhood of minimum solar activity.

LSA and MSA foF1 data are grouped into March Equinox (comprising months of Febuary, March and April), June Solstice (comprising months of May, June and July), September Equinox (comprising months of August, September and October) and December Solstice (comprising months of November, December and January), following the examples of [1], [17], [18], [2], [3], [4], in order to investigate seasonal effects. Latitudinal comparison is performed between July foF1 VRof Ibadan and those of Singapore and Slough due to availability of data.

Relative variability of foF1 is obtained using the quotient of standard deviation, σ and mean value, μ, of foF1 following the example of [9]. Relative variability (VR) is defined, statistically as

$$VR\ (\%) = \frac{\sigma}{\mu}\ x\ 100 \quad (1)$$

The VR is a statistical tool that describes the extent of spread or deviation of each data point from the calculated mean of the entire data set. Though some authors obtain VR by the quotient of interquartile range and median, i.e

$$VR\ (\%) = \frac{q75 - q25}{median}\ x\ 100 \quad (2)$$

The advantage of using Eq. (1) over Eq. (2) has been mentioned by [5]. "[18]" pointed out that the only disadvantage of the method in equation (1) is that of difficulty in interpretation in terms of probability.

3. Results and Discussion

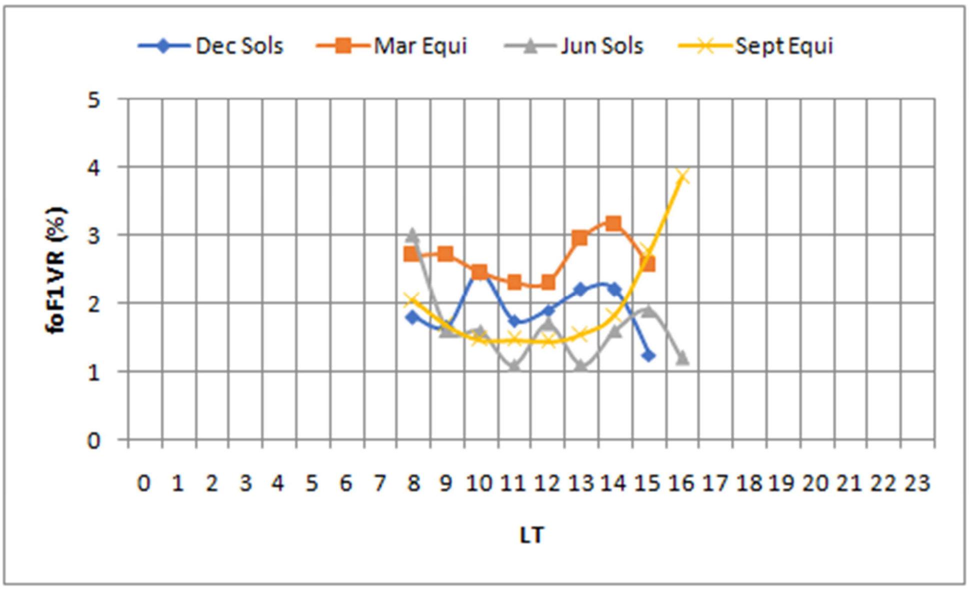

Figure 1. Diurnal variation of foF1 Relative Variability (VR) for all seasons during a year of Low Solar Activity (1965).

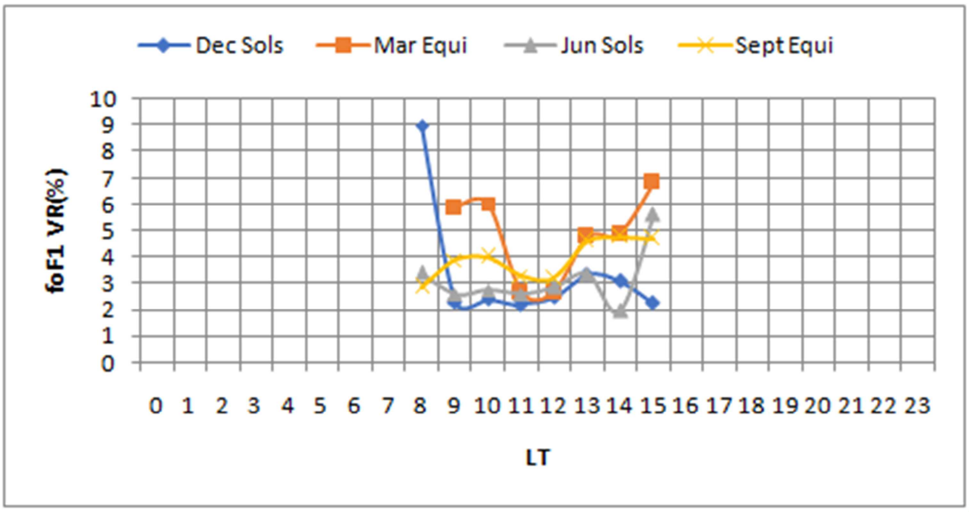

Figure 2. Diurnal variation of foF1 Relative Variability (VR) for all seasons during a year of Moderate Solar Activity (1973).

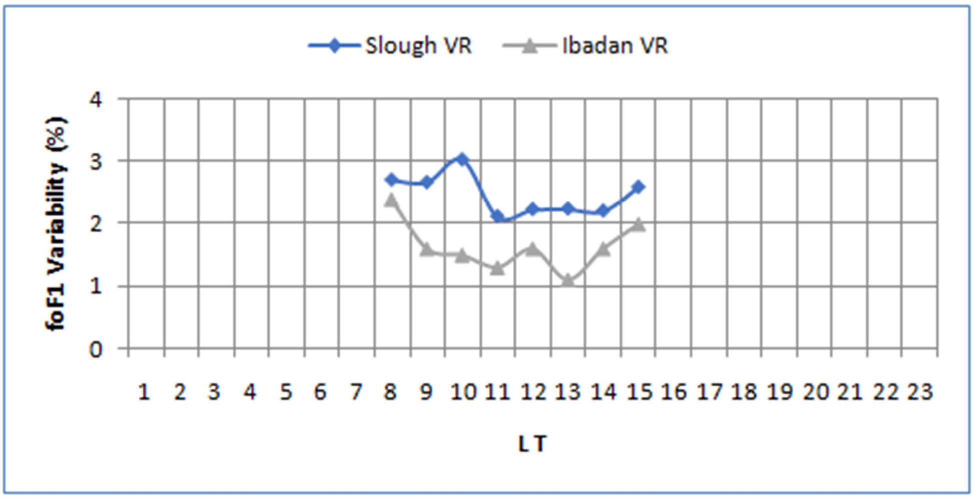

Figure 3. Diurnal variation of foF1 Relative Variability (VR) for Slough Singapore and Ibadan during July 1965 (Low Solar Activity).

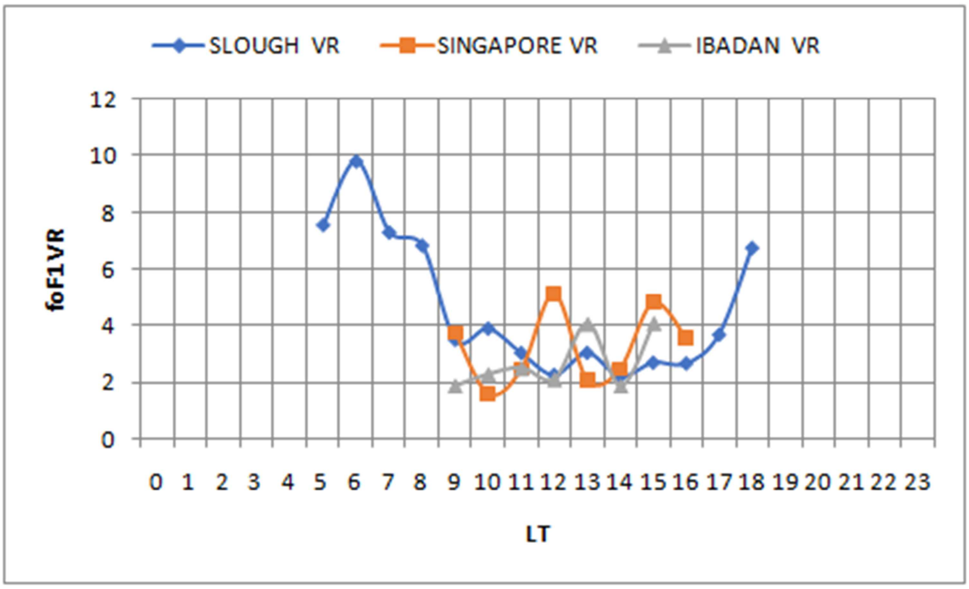

Figure 4. Diurnal variation of foF1 Relative Variability (VR) for Slough, Singapore and Ibadan during July 1971 (Moderate Solar Activity).

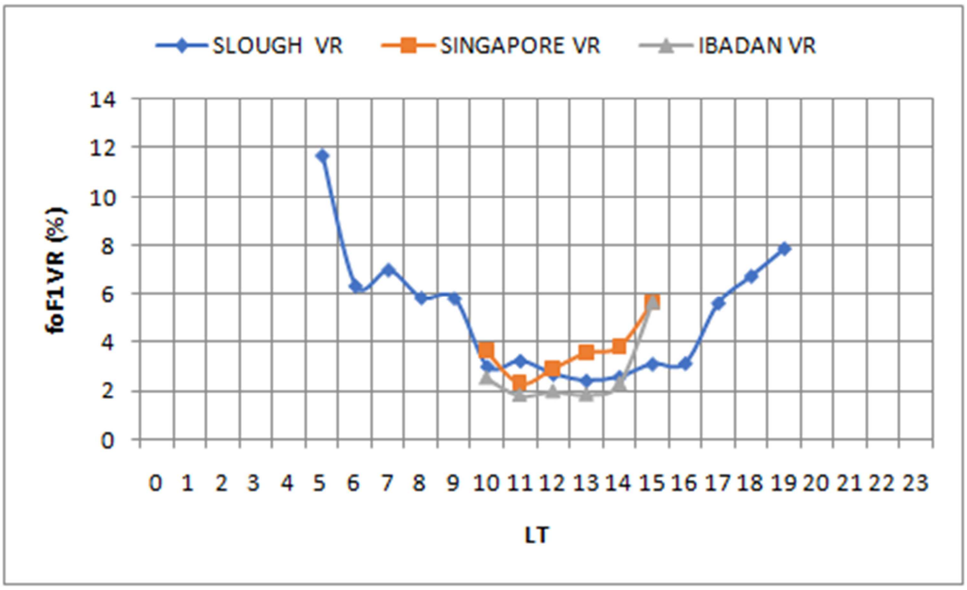

Figure 5. Diurnal variation of foF1 Relative Variability (VR) for Slough, Singapore and Ibadan during July 1968 (High Solar Activity).

The diurnal plots of the variability (VR) of monthly average of foF1 values at Ibadan are shown in figures 1 and 2 so as to observe the diurnal and seasonal influence during low solar activity (LSA) and moderate solar activity (MSA). During high solar activity (HSA) it is only at the summer solstice that foF1 values are present for any meaningful observation. This observationis in agreement with that of [1] who mentioned that well defined F1 layers were observed only during summer of HSA. Being a daytime phenomenon, F1 ledge is observed between 08:00 hour to 16:00 hour. It is sometimes not observed until 10:00 hour and also disappears as early as 14:00 hour. "[19]" mentioned that the times of onset of F1 layer in the morning and its disappearance in the afternoon are variable from day to day. Thus, unlike the E layer, another Chapman layer characteristic peaks of foF1 VR are not observed in the neighbourhood of sunrise and sunset. VR of foF1 are about the same order of magnitude at all the seasons differing slightly from each other. It is in the range (1.2% to 2.4 %), (2.3% to 3.2%), (1.1% to 3%) and (1.5% to 3.8%) during December Solstice, March Equinox, June Solstice and September Equinox respectively during year of low solar activity (LSA). These values compare with foE VR values in the range 0.5 to 4% during LSA.

During moderate solar activity (MSA), the range of foF1 VR are (2.3% - 9%), (3% - 6.9%), (2% - 5.5%) and (3% - 4.8%) for December solstice, March Equinox, June solstice and September Equinox, respectively. Compared with foE VR values (1.5 – 6%) during MSA, obtained by [17], foF1 VR is slightly greater than foE VR, in general.

The VR of foF2 during the day (2% - 15%) for LSA and (4 – 12%) for MSA obtained by [16] is expectedly greater than foF1 VR which is in the range (1- 3.8%) and (2- 9%) during LSA and MSA, respectively as shown in Figures 1 and 2. "[20]" mentioned that the the F1 layer partakes of the regularity of the E- layer and the variability of the F2 layer. This possibly explains the reason for greater foF1 VR than foE VR and lesser foF1 VR than foF2 VR. The F1 layer is more pronounced during LSA than during MSA. Thus foF1 is expectedly more irregular during MSA than during LSA. "[13]" pointed out that irregularity in occurrence of ionospheric parameters and not only because the mean value is low, as mentioned by [5], leads to greater relative variability. On seasonal scale, though the diurnal trend varies at all the stations during LSA and MSA, Figures 1 and 2 show that foF1 VR is greater during March equinox.

The greater foF1 VR during MSA than during LSA contrary to observation of lower relative variability as solar activity increases, for other ionospheric parameters [3], [14], [15], [16], [18], [19], are due to the occurrence of greater absolute variability during MSA than during LSA.

In order to investigate latitudinal influence, diurnal plots of July foF1 VR of Ibadan, (6 ^{o}S dip) Singapore (17.6 ^{o}S dip) and Slough (66.5 ^{o}N) during LSA, MSA and HSA are shown in Figures 3 to 5. No data however available for foF1 of Singapore during LSA. While pre-sunrise and post-sunset peaks are observed for Slough, a mid latitude station, they are not found for Ibadan and Singapore. This is due to the non-appearance of F1 layer outside the hours in between 08:00 and 16:00. It should be mentioned that while F1 is present at Slough at Summer during all epochs of solar cycle it is either not found at all or very scanty at the summer of very high solar activity (VHSA, Rz > 150) at the low latitude stations of Singapore and Ibadan. "[8]" explained that the F1 layer is weakest near the maximum of the sunpot cycle. This observation seems applicable to the equatorial and low latitude region than to the mid latitude, possibly because, as [19] put it, the F1 layer is enhanced by decrease in solar activty. At the equatorial and low latitude stations the impact of solar activity is more than at the mid latitude, the solar zenith angle being much larger at mid latitude than at low latitude and the equator.

It is pertinent to point out that the pre-sunrise peak of foF1 at Slough occurred earlier during LSA than during MSA and HSA.

Comparison of foF1 VR of 08:00 – 16:00 hour at the three stations show that foF1 VR is greater at Singapore than at Ibadan and at Slough during HSA and MSA (No data is available for Singapore during LSA). This is probably because Singapore is just below the crest of equatorial anomaly which is known for its highly variable dynamics [11], [2].

4. Conclusion

The characterization of the day - to - day variability (VR) of the critical frequency of F1 layer (foF1) on diurnal and seasonal scale at the equatorial stations of Ibadan (7.4°N, 3.9°E, 6°S dip), Singapore (1.3°N, 103.8°E, 17.6°S dip) and Slough (51.5°N, 359.4°E, 66.5°N dip) during low solar activity (LSA) and moderate solar activity (MSA) has been undertaken. Also studied is the effect of latitude on the variability. It is observed that:

(i) while foE VR is less than foF1 VR, foF2 VR is greater than foF1 VR.

(ii) foF1 VR MSA is greater than foF1 VR LSA

(iii) foF1 VR pre- sunrise and post – sunset peaks exist for mid latitude but not for low latitude/equatorial stations.

(iv) foF1 VR is not found at the summer of VHSA (Rz > 150).

(v) foF1 VR is found at the summer of all epochs of solar cycle at the mid latitude station of Slough.

(vi) Daytime (10:00h – 16:00h) foF1 VR is greater at Singapore and Ibadan than at Slough.

(vii) On seasonal scale, foF1 VR is greater during March Equinox for both LSA and MSA

The variability of foF1 is found to be of order (1-3.8%) during LSA and (2-9%) during MSA. On the seasonal scale foF1 VR is greater during March Equinox for both epochs. Comparison of foF1 VR with foE VR and foF2 VR shows that foF1 VR is of the same order of magnitude (0.5 to 4%) during LSA and slightly greater than foE VR (1.5 - 6%) during MSA, in general. It is less than foF2 VR (2 – 15%) during both epochs. On a general note, daytime (10:00 h - 16:00 h) foF1 VR is greater at Singapore (1.8 – 5.8%) and at Ibadan (1.8 – 5.8%) than at Slough (2.2 – 4.0%). While pre-sunrise and post-sunset peaks are apparent at Slough, they are not at Singapore and Ibadan. Moreover, in order for ionospheric models to be successful, description of F1 layer variability is important.

References

[1] Adeniyi (1996). “Equatorial F1 characteristics and the international reference ionosphere model” *Radio Science,* 31(4), pp 893–897.

[2] Akala, A. O., Oyeyemi, E. O., Somoye, E. O, Adeloye, A. B., Adewale, A. O (2010) “Variability of foF2 in the African equatorial ionosphere*” J. Adv. Space Res.,* 45, pp 1311-1314.

[3] Akala, A. O., Somoye, E. O., Adeloye, A. B. and Rabiu, A. B. (2011). “Ionospheric foF2 variability at equatorial and low latitudes during high, moderate and low solar activity,” *Indian J. Radio Space Phy.* 40, pp. 124–129.

[4] A. O. Akala, L. L. M. Amaechi, E. O. Somoye, R. O. Idolor, E. Okoro, P. M. Doherty, K. M. Groves, C. S. Carrano, C. T. Bridgwood, P. Bati, F. M. D’ujanga, and G. K. Seemala,(2015).”Climatology of GPS amplitude scintillation over equatorial Africa during the minimum and ascending phases of solar 24,” *Astrophys. Space Sci*., 357: 17, doi: 10.1007/s10509–015–2292-9.

[5] Bilitza, D., Obrou, O. K., Adeniyi, J. O., Oladipo, O. (2004). Variability of foF2 in the equatorial ionosphere. *Advances in Space Research,* 34, pp1901-1906.

[6] Bilitza, D. (2000). "International Reference Ionosphere 2000". *Radio Science,* 36 (2), pp 261–275. doi:10.1029/2000RS002432

[7] Basu S., Groves K. M., Basu S. U. and Sultan J. P. (2002).“Specification and forecasting of Scintillation in communication/navigation links: Current status and future plans”. *J. Atmos Sol-Terr. Phys.* 64, 1745–1754.

[8] Craig, R. A. (1965). “The Upper Atmosphere” Chapter 9. *Academic Press,* New York and London.

[9] Forbes, J. M., Palo, S. E. and Zhang, X. (2000). “Variability in the ionosphere”. *J. Atmos. and Solar-Terr. Phys.* 62 (2000), pp 685-693.

[10] Ratcliffe, J. A and Weekes, K (1960). “The ionosphere in “Physics of the Upper Atmosphere” (J. A. Ratcliffe, ed.), pp 390, 426, 433 and 454. *Academic Press*, New York.

[11] Rishbeth, H., Mendillo, M. (2001). “Patterns of F2- layer variability”. *J. Atmos. Solar Terrs. Phys.* 63, pp 1661–1668.

[12] Somoye, E. O. (2009). “Periodicity of Solar Cycle from Diurnal Variations of foF2 at Ibadan”. *International Journal of Physical Sciences,* 4 (3), pp 111-114.

[13] Somoye, E. O. (2009). “Comparison of NmF2 Variability at Ibadan, Singapore and Slough during different Epochs of Solar Cycle”. *Asian J. Scientific Res.*, 2, pp 155-160.

[14] Somoye, E. O., Akala, A. O. (2010) “NmF2 Variability at Equatorial and Low Latitude Stations: A review”. *Research Journal of Physics,* 4 (2), pp 50–55.

[15] Somoye, E. O., Akala, A. O. (2011) “Comparison of diurnal, seasonal and latitudinal effect of MUF VR and NmF2 VR during some solar cycle effect”. *Advances in Space Research,* 47, pp 2182–2187.

[16] Somoye, E. O., Akala, A. O., Ogwala, A., (2011). “Day to day variability of the h’F and foF2 during some solar epochs”*J. Atmos. Solar-Terr. Phy.* 73, pp 1915–1922.

[17] Somoye, E. O., Onori, E. O. and Akala, A. O. (2013). “Comparison of foE and M(3000) F2 variability at Ibadan, Singapore and Slough”. *J. of Atmospheric and Solar-Terestrial Physics,* 92, pp 18–22.

[18] Somoye, E. O., Akala, A. O., Adeniji-Adele, R. A., Iheonu, E. E., Onori, E. O., Ogwala, A. (2013). “Equatorial F2 characteristic variability: a review of recent observations”. *J. Adv. Space Res.,* 52, pp 1261–1266.

[19] VanzandtT. E. (1967). The neutral Atmosphere and the quiet ionosphere, in “Physics of Geomagnetic phenomenon” (S. Matsushita and Campbell W. H., ed.) *Academic Press,* New York.

[20] Zhang, M. L., Shi, J. K., Wang, X., Radicella, S. M. (2004).“Ionospheric variability at low latitude station: Hainan, China”. *J. Adv. Space Res.,* 34, pp 1860-1868.