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Comparison of Absolute and Relative Variability of F2 Layer Critical Frequency in West Africa Using Ionosonde Station at Ibadan

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Abstract

This paper presents the comparison of the absolute variability (σ) and relative variability (VR) of the critical frequency of F2-layer (foF2) at Ibadan (7.4°N, 3.9°E, 6°S dip) an equatorial station in the West African regionduring years of high, moderate and low solar activities for the seasons represented with the months of March, June, September and December are studied. Diurnal and seasonal variations of the absolute and relative variability obtained are compared. The results showed that relative variability of foF2 is more useful in representing the variability of foF2 than the absolute variability of foF2.

Keywords

foF2, Absolute Variability, Relative Variability, Solar Activity

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1. Introduction

The existence of the ionosphere is directly related to radiations emitted from the sun. The movement of the earth round the sun and changes in the sun's activities results in ionospheric variations. "[1]" pointed out that proper understanding of ionospheric variability from various aspects, such as, characterization, causative mechanisms, and prediction, has remained on the priority list of the aeronomy community. And as a step toward such understanding, and for the benefit of improving existing forecasting models, it is important to quantify the extent of spread or deviation of ionospheric parameters (at different locations and times) from their statistical means. However, many authors have worked on the quantification for different ionospheric parameters at different latitudes and solar cycle spread using different measures of dispersion. For instance, [16], [2], [1], [6], [12], [10], [15], [13], [4], [11], [5], [20], [7], [19] and [3] among others have investigated the variability of NmF2, foF2, hmF2, and MUF. Furthermore, the quantification of ionospheric parameters can be analyze by means of some statistical tools such as the mean (μ), median, absolute variability (σ), relative variability (VR) among others.

Absolute variability (σ) also called standard deviation is defined as the square root of the variance. Variance (V) is a measure of distribution of data, showing how the data lies far or near from the mean. It is given by equation below

$$\sigma = \sqrt{\frac{\Sigma(X-\mu)^2}{N}} \tag{1}$$

where x is the foF2 value, N is the total number of the data set.

Relative variability (VR) on the other hand is a statistical instrument that describes the extent of spread or deviation of

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each data from the calculated mean for the entire data set. It is the ratio of the absolute variability (standard deviation) to the mean of the data express as percentage. It is given by equation below.

$$VR(\%) = \frac{\sigma}{\mu}x100 \tag{2}$$

where σ absolute variability is also called standard deviation and μ is the mean of foF2 value.

Relative variability (VR) is very useful because its value is normalized and it is dimensionless and hence can be used to directly compare different data.

The present study is aim at comparing the diurnal and seasonal variation of the relative and absolute variability of foF2 during year of high solar activity HSA (1958), moderate solar activity MSA (1973) and low solar activity LSA (1965) for the different seasons of each year represented by the months of March, June, September and December.

After section 2 where we present the data used in the present study and our methodology, section three present our results and discussion while section 4 concerns the conclusion of the paper.

2. Data and Method

The data used for this study are foF2 mean hourly values obtained from the monthly bulletins of Ionospheric station at Ibadan (7.4°N, 3.9°E, 6°S dip) in Nigeria. The values were measured by the Union Mark II Recorder type ionosonde described in details by [17]. The data include those of 1958 (High Solar Activity) with yearly mean sunspot number Rz = 184.6, 1973 (Moderate Solar Activity) with yearly mean sunspot number Rz =38.0 and 1965 (Low Solar Activity) with yearly mean sunspot number Rz = 15.1. The data sets used cover the months of March, June, September and December of each of the year under investigation. These months were used as representative months for the four seasons that is March equinox comprising (February, March and April), June solstice comprising (May, June and July), September equinox comprising (August, September and October) and December solstice comprising (November, December and January).

The method applied is the statistical approach used by [10], [4], [1], [18]where the VR of foF2 are computed as the ratio of the absolute variability (σ) to the monthly mean (μ) of the foF2 data multiply by 100 as shown earlier inequation 2. That is

$$VR(\%) = \frac{\sigma}{\mu}x100$$

where σ absolute variability is also called standard deviation and μ is the monthly mean of foF2 values.

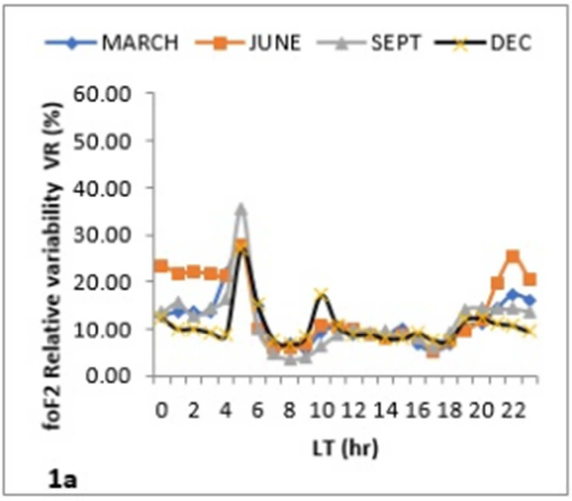
Standard deviation or absolute variability is computed from equation 1 given by

$$\sigma = \sqrt{\frac{\sum(X-\mu)^2}{N}}$$

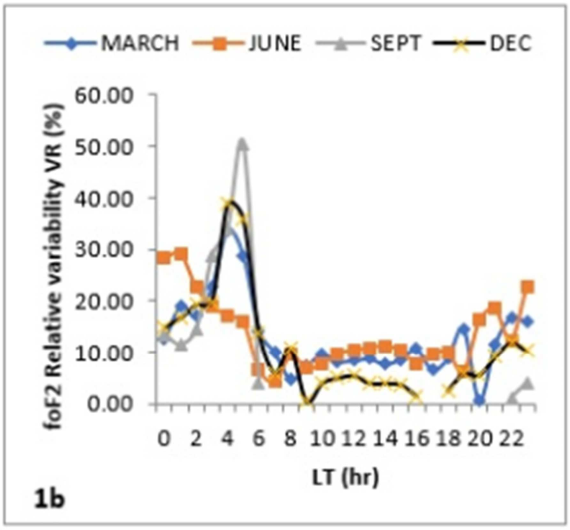
where x is the foF2 values, N is the total number of the foF2 data set.

The comparison of the diurnal variation of foF2 relative and absolute variability was done by plotting their values against 24 hours local time (LT) of the day for the four seasons of each of the solar activity years that is 1958 (a year of high solar activity), 1973 (a year of moderate solar activity) and 1965 (a year of low solar activity).

3. Result and Discussion



1a



1b

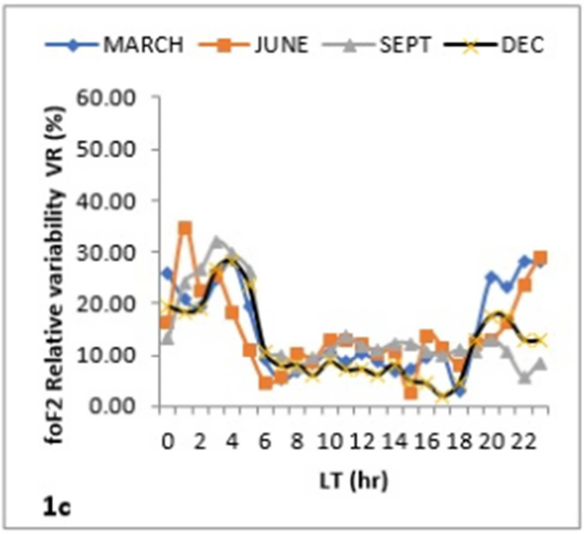
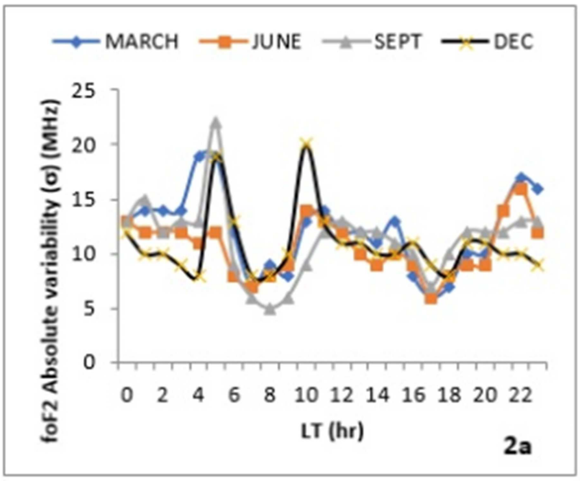
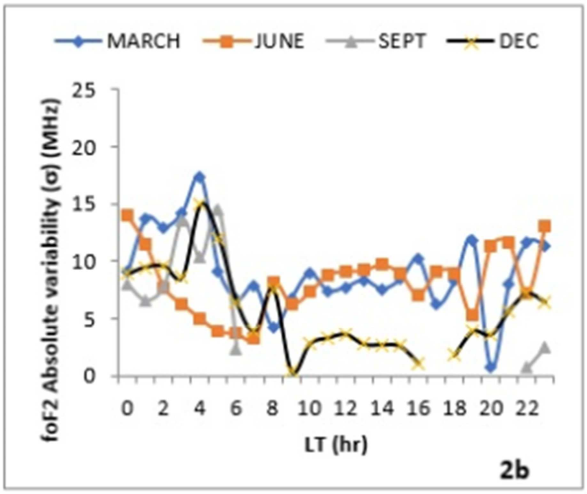


Figure 1. Diurnal variation of foF2 Relative variability (VR) for all seasons during a year of (a) High Solar Activity (HSA), 1958 (b) Moderate Solar Activity (MSA), 1973(c) Low Solar Activity (LSA), 1965.





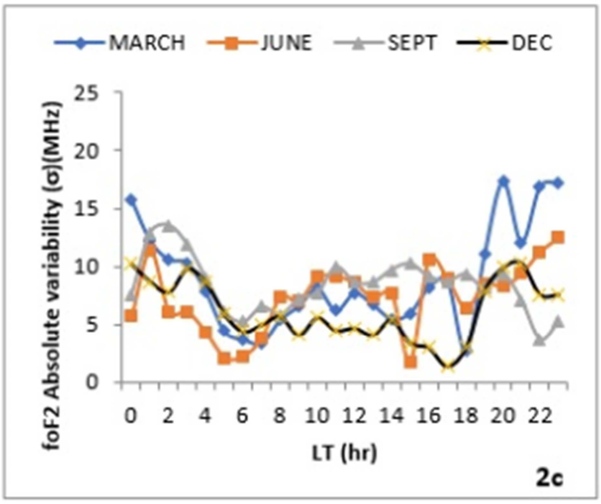


Figure 2. Diurnal variation of foF2 Absolute variability (σ) for all seasons during a year of (a) High Solar Activity (HSA),1958 (b) Moderate Solar Activity (MSA),1973 (c) Low Solar Activity (LSA),1965.

Figures 1(a)-(c) show the plots of diurnal variation of relative variability (VR) of foF2 against local time (LT) for all seasonsduring year of high, moderate and low solar activities and figure 2(a)-(c) show the diurnal plots of absolute variability (σ) of foF2 against local time (LT) for all seasonsduring year of high, moderate and low solar activities.

From figures 1(a)-(c) all the plots have the same diurnal features (comparatively high VR during night time and low during the day). During the night time, foF2 relative variability attains it highest values of 35% in September, 50% in September and 35% in June in the year of high, moderate and low solar activity respectively. Also, all the plots of relative variability of foF2 are characterised by two peaks. The highest peak is observed to occur during post mid-night hour and the second peak during post sunset hours. This compares well with the work of [2], [1]whose plots of coefficient of foF2 variability with (LT) follows the same pattern. The reason for these peaks according to [4], [7]is due to steep electron density gradients that are caused by the onset and turn off of solar ionization that is the peaks actually occur at periods of sunrise and sunset. “[14]” reported that another reason for this may be due to the complex nature of the F2 layer characteristics vertical drift driven by the electric and magnetic field (*E X B*) force of the Earth’s magnet at the equatorial region. In the equatorial region the electric field E in conjunction with the earth’s magnetic field B produces the *E X B* force that causes vertical drift of ionisation. The direction of *E X B* force is upward during the daytime and downward during the nighttime, hence there is upward drift of plasma during the daytime and downward drift of plasma during the nighttime. Investigations have revealed that the vertical drift velocity depends on season and phase of solar cycle [5], [9], [8].

From figures 2(a)-(c), on the other hand the plots of absolute variability against LT do not show the same diurnal features and characteristics peak patterns as relative variability of foF2 for the three solar years under consideration.

Absolute variability (σ) of foF2 from figures 2(b) and 2(c) is observed to be high during the night time and low during the day during year of moderate and low solar activity that is 1973 and 1965 but it is high for both the day and night time hours during year of high solar activity 1958 as observed from figure 2(a). "[4]" mentioned that the relative variability VR is greater at night because of low value of NmF2 at these hours of the day, this is partly responsible for the minor peak around noon observed from figure 2(a). Furthermore, according to "[17]", this observation might also be as a result of noon-bite-out caused by *E X B* drift of ionization. Diurnal features of foF2 absolute variability is not consistent as compare to diurnal features of foF2 relative variability (VR). This may be due to the normalised nature of foF2 relative variability (VR).

During the day, foF2 absolute variability (σ) attains it highest value of 20MHz in December during the day in high solar activity year (1958). Meanwhile, during the night time, foF2 absolute variability (σ) attains it high values of 22MHz in September (1958), 17MHz in March (1973) and 17MHz in March (1965) for years of high, moderate and low solar activity respectively. All the plots of figures 2(a)-(c) do not show the same characteristics peaks as observed with relative variability (VR) of foF2 shown in figure 1(a)-(c). From Figures 1b and 2b, there is little variability in the morning hours in June as compared to the other season at solar moderate conditions. The reason for this is not clearly known and requires further investigation with more set of average data.

Observation from figures 1(a)-(c) and 2(a)-(c) showed that relative variability (VR) of foF2 increase with decrease in solar activity while absolute variability (σ) of foF2 increase with increase in solar activity. This is in line with the work of previous researchers cited in this study. The highest value of foF2 relative variability (VR) 50% occurred during year of moderate solar activity while that of foF2 absolute variability (σ) 22MHz occurred during year of high solar activity.

4. Conclusion

We presented comparison of the absolute variability (σ) and relative variability (VR) of foF2 at Ibadan during year of high, moderate and low solar activity. The analysis and comparison from the study shows that foF2 relative variability (VR) is more reliable and better used than foF2 absolute variability (σ) in expressing the variability of the critical frequency of the F2 layer (foF2) and other ionospheric parameters. The highest seasonal value of relative variability VR occurred during the September equinox during the MSA year while that of absolute variability occurred in September equinox during HSA year. The study also showed that foF2 relative variability (VR) is more susceptible to variability during night-time than the day time. The results revealed that as solar activity reduces relative variability of foF2 increases. The reverse is the case with absolute variability (σ) of the critical frequency of the F2 layer (foF2).

References

[1] Akala, A. O., Somoye E. O., Adeloye, A. B. and Rabiu, A. B. (2011). Ionospheric foF2 variability at equatorial and low Latiatudes during high, moderate and low solar activity. Indian J. Radio and Space Physics, 40, 124-129.

[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. Advances in Space Research, 45. 1311-1314.

[3] Atac, A., Ozguc, A., Pektas, R. (2009). The variability of foF2 in different phases of solar cycle 23. J. Atmos. Solar-Terr. Phys. 71, 583–588.

[4] Bilitza, D., Obrou, O. K., Adeniyi, J. O., Oladipo, O. (2004). Variability of foF2 in the equatorial ionosphere. Adv. Space Res. 34, 1901–1906.

[5] Balan N. and G. J., Bailey (1995). Equatorial plasma fountain and its effects: Possibility of an additional layer; J. Geophys. Res., 100, 21, pp 421–432.

[6] Chandra, H., Som Sharma and Soe Win Aung, (2009). Day to Day variability in the critical frequency of F2 layer over the anomaly crest region, Ahmedabad. J. Ind. Geophys. Union. 13, 217-226

[7] Chou, Y. T., Lee, C. C. (2008). Ionospheric variability at Taiwan low latitude station: comparison between observations and IRI-2001 model. Adv. Space Res. 42, 673–681.

[8] Fejer, B. G., Scherliess, L., Paula, E. R. (1999). Effects of vertical plasma drift velocity on the generation and evolution of equatorial spread F. J. Geophys. Res. 104, 19859–19869.

[9] Fejer, B. G., Farley, D. T. (1979). Dependence of equatorial F region vertical drift on season and solar cycle. J. Geophys. Res. 84, 5792–5796.

[10] Forbes, J. M., Palo, S. E., Zhang, X. (2000). Variability of the ionosphere. J. Atmos. Solar-Terr. Phys.62, 685–693.

[11] Fotiadis, D. N., Baziakos, G. M., Kouris, S. S. (2004). On the behaviour of the dayto- day MUF variation. Adv. Space Res. 33, 893–901.

[12] Jayachandran, B., Balachnadran Nair, R., Balan, N., Rao, P. B. (1995). Short term variability of the ionospheric electron content and peak electron density during solar cycles for a low latitude station. J. Atmos. Solar-Terr. Phys. 52 (13), 1599–1605.

[13] Kouris, S. S., Fotiadis, D. N. (2002). Ionospheric variability: a comparative statistical study. Adv. Space Res. 29 (6), 977–985.

[14] Oladipo O. A., J. O. Adeniyi, S. M. Radicella, I. A. Adimula. (2011). Variability of the ionospheric electron density at fixed heights and validation of IRI-2007 pofile's prediction at Ilorin. Adv. Space Res. 47, 496–505.

[15] Rishbeth, H., Mendillo, M. (2001). Patterns of F2-layer variability. J. Atmos. Solar-Terr. Phys. 63, 1661–1680.

[16] Somoye, E. O., Akala, A. O. (2010). NmF2 Variability at Equatorial and Low Latitude Stations: A review Res. J. Phy. 4(2), 50–55.

[17] Somoye, E. O. (2009a). Comparison of NmF2 variability at Ibadan, Singapore and Slough during different epochs of solar Cycle. Asian J. Sci. Res., 2. 155-160.

[18] Somoye, E. O., E. O. Onori, A. O. Akala (2013). Comparison of foE and M(3000)F2 variability at Ibadan, Singapore and Slough. J. Atmos. Solar-Terr. Phys. 82, 18–22.

[19] Zhang, M. I., J. K. Shi, X. Wang and S. M. Radicella (2004). Ionospheric variability at low latitude station: Hainan, China, Advances in Space Science, 34, pp 1860-1868.

[20] Zhang, S. R., Holt, J. M. (2008). Ionospheric climatology and variability from long-term and multiple incoherent scatter radar observations: variability. Ann. Geophys. 26, 1525–1537.