Comparison of absolute and relative variability of *foF2* at Ibadan

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ABSTRACT
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) during high (1958), moderate (1973) and low (1965) solar activity for the months of March, June, Sept and December is studied. Diurnal variation of the absolute and relative variability's obtained are compared. The results show 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

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. Akala et al (2011) 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.

Its noteworthy that 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, Somoye et al (2010), Akala et al (2010) and (2011). Chandra et al (2009). Jayachandran et al. (1995). Forbes et al. (2000). Rishbeth and Mendillo (2001). Kouris and Fotiadis (2002), Bilitza et al. (2004), Fotiadis et al. (2004), Bradley et al. (2004), Zhang et al. (2007),Chou and Lee (2008) and Atac et al. (2009) among others have investigated the variability of *NmF2*, *foF2*, *hmF2*, and *MUF*. Furthermore, the quantification of ionospheric parameters can be analyzed 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 (2) below.

Relative variability (*VR*) on the other hand is statistical tool that describes the extent of spread or deviation of 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 1 below. 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 variation of the relative and absolute variability of *foF2* during year of high (1958), moderate (1973) and low (1965) solar activity for the months of March, June, September and December.

Data and Method

The data used for this study are *foF2* mean hourly values of Ibadan (7.4°N, 3.9°E, 6°S dip). The values were measured by the Union Radio Mark II Recorder type ionosonde described in

details by Somoye (2009). The data include those of 1958 (High Solar Activity) with yearly mean sunspot number R_z = 172.1. 1973 (Moderate Solar Activity) with yearly mean sunspot number R_z =36.7 and 1965 (Low Solar Activity) with yearly mean sunspot number R_z = 12.1. The data sets used cover the months of March, June, September and December of each of the year under investigation.

The method applied is the statistical approach used by Forbes et al (2000) and Bilitza et al (2004) where the *VR* of *foF2* are computed as the ratio of the absolute variability (σ)to the mean (μ) of the data (*foF2* values) multiply by 100 as shown in the equation (1)

$$VR(\%) = \frac{\sigma}{\mu} x100 \qquad (1)$$

Where σ is absolute variability also called standard deviation and μ is the mean of *foF2* value.
Standard deviation or absolute variability is computed from equation (2)

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

Where X is the *foF2* value, *N* is the total number of the data set.

The comparison of the diurnal variation of *foF2* relative and absolute variability was done by plotting their values against local time of the day for the 4 months of each of the solar activity year ie 1958 (year of high solar activity), 1973 (year of moderate solar activity) and 1965 (year of low solar activity).

Results and Discussion

Figures 1(a)-(c) show the plots of diurnal variation of relative variability of *foF2* against local time (LT) during year of high, moderate and low solar activities and Figures 2(a)-(c) show the diurnal plots of absolute variability of *foF2* against local time (LT) during year of high, moderate and low solar activities.

Figures 1(a)-(c) show that 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 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 midnight hour and the second peak during post sunset hours. This agrees with the works of Akala et al (2010, 2011) whose plots for coefficient of foF2 variability with (LT) follow the same pattern. The reason for these peaks according to Bilitza et al (2004) and Chou and Lee (2008) is due to steep electron density gradients that are caused by the onset and turn off of solar ionization whose peaks actually occur at periods of sunrise and sunset.

Figures 2(a)-(c), on the other hand appear to indicate that the plots of absolute variability against LT do not show the same diurnal features and characteristics peak patterns as the 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 i.e. 1973 and 1965 but is high for both the day and night time hours during year of high solar activity i.e. 1958 as observed from Figure 2(a). It is significant to observe that Bilitza et al (2004) had 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 Somoye, (2009), this observation might also be as a result of noon-bite-out caused by *ExB* 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

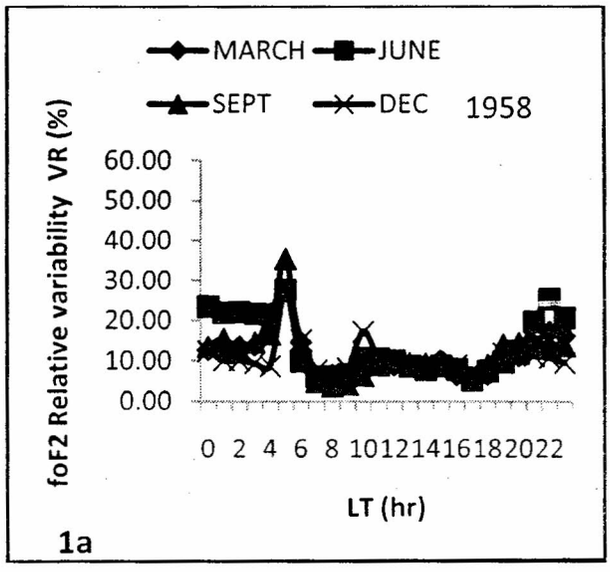
to the normalised nature of *foF2* relative variability (*VR*).

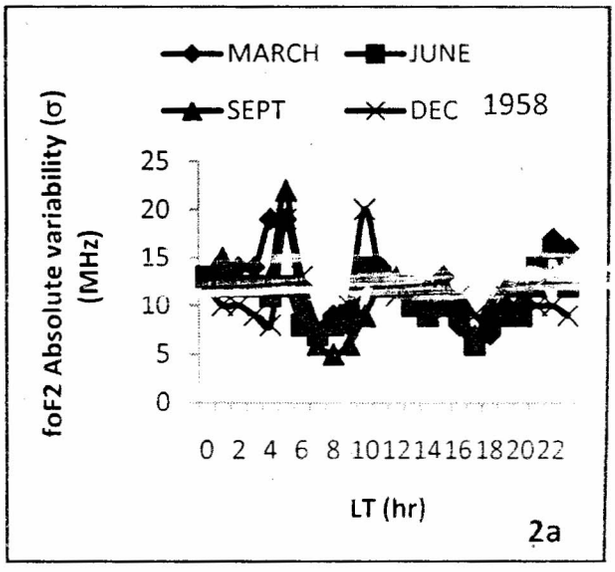
During the day, *foF2* absolute variability (σ) attains it highest value of 20MHz in December during year of high solar activity (1958). Meanwhile, during the night time, *foF2* absolute variability (σ) attains it highest value of 22 MHz in September (1958), 17 MHz in March (1973) and 17 MHz in March (1965) for year 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 Figures 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 agrees with the work of previous researchers cited in this study. The highest value of 50% foF2 relative variability(*VR*) occurred during year of moderate solar activity and that of foF2 absolute variability (σ) of highest value 22 MHz occurred during year of high solar activity.

Conclusion

We have 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 results obtained from the study show that *foF2* relative variability (*VR*) is more reliable and better used than *foF2* absolute variability (σ) in expressing the variability of *foF2* and other ionospheric parameters. The study also showed that *foF2* relative variability (VR) is more susceptible to variability during night-time than the day time. The results further reveal that as solar activity reduces relative variability of foF2 increases. And the reverse is the case with absolute variability (σ) of *foF2*.





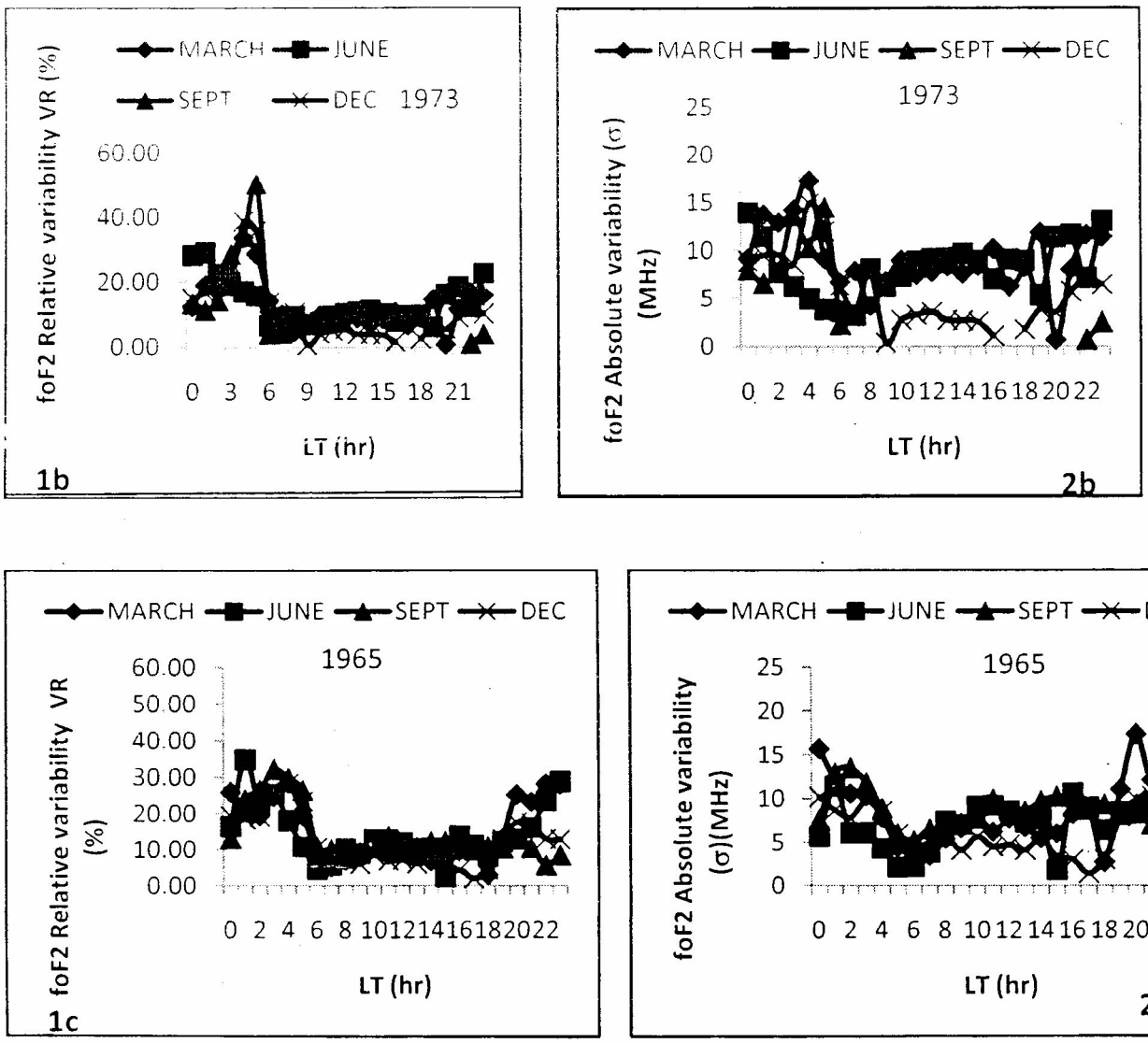


Figure 1: Diurnal variation of foF2 Relative variability VR for all seasons during a year of (**a**) High Solar Activity, 1958 (**b**) Moderate Solar Activity, 1973 (**c**) Low Solar Activity, 1965

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

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