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Comparison of NmF2 Variability at Ibadan, Singapore and Slough during Different Epochs of Solar Cycle

E.O. Somoye
Department of Physics, Lagos State University, P.M.B. 1087, Apapa, Lagos, Nigeria

Abstract: NmF2 variability, VR, at Ibadan (7.4°N, 3.9°E, 6°S dip) is investigated for diurnal and seasonal changes during low, moderate and high solar activity. It is also compared with those of Singapore (1.3°N, 103.8°E, 17.6°S dip) and Slough (51.5°N, 359.4°E, 66.5°S dip). NmF2 absolute VR (and not only relative VR) is greater during the night and slightly greater around noon than during other daytime hours. While, daytime NmF2 shows no seasonal variation, night time NmF2 is greater during the equinoxes at low and moderate solar activity and during the equinox and June solstice at high solar activity. Daytime VR found not to show latitudinal difference during moderate solar activity is observed to increase with latitude during high solar activity. Nighttime VR is found to decrease with latitude during high solar activity. While, NmF2 VR at Ibadan and Singapore are found to decrease alternately with sunspot number, R, that of Slough is observed to increase with R during about the first half of the day and to decrease with R during the other part.

Key words: Absolute VR, diurnal variation, NmF2, relative VR, seasonal variation, sunspot number, variability

INTRODUCTION

Of all the variations observed in the ionosphere, that of day- to- day appears to be the most random. Kouris and Fotiadis (2002) found that the variability of foE, foF2, M (3000) F2 and MUF (3000) F2 from day-to-day is greater than the variability from hour to hour for instance. This day-to-day variability is expected to change diurnally and annually since the sun's zenith angle change with the hour and the month, respectively. The variability, be it diurnal or monthly should also change with epochs of solar cycle due to changes (variation) in solar activities during the solar cycle.

The purpose of this study is to investigate the NmF2 (maximum electron density of F2) variability layer at the low latitude station of Ibadan, Nigeria (7.4°N, 3.9°E, dip 6°S). NmF2 relative variability is said to be high during the night at low latitude stations partly due to low values of NmF2 at night (Bilitza *et al.*, 2004; Rishbeth and Mendillo, 2001). The other reason is sought by comparing NmF2 relative variability with its absolute variability. Comparison of NmF2 variabilities of Ibadan is also made with those of Singapore (1.3°N, 103.8°E, 17.6°S dip) and Slough (51.5°N, 359.4°E, 66.5°S dip).

MATERIALS AND METHODS

Values of relative variability, VR, of NmF2 are obtained from the ratio of standard deviation, σ and mean, X of NmF2 i.e.,

$$VR\,(\%) = \sigma / X \times 100 \quad (1)$$

From NmF2 = $1.24\times10^{10} f^2$ (where f is the critical frequency of F2 layer), values of NmF2 are obtained.

Values of foF2 are obtained from the records of the ionosonde, the Union Radio Mark II recorder type developed at the Radio Research Station in Slough. The transmitter and receiver of the ionosonde are separate sub-units kept in tune by a frequency sensitive servo gerro-system. Pulses are transmitted over a range of 0.7 to 25 MHz in a sweep time of five minutes duration. The time interval between the transmitted pulses and their echoes are then recorded photographically. Variation of apparent height, (h) with frequency (f) of radio waves is shown on the records, referred to as ionograms. NmF2 variabilities of January to December 1958, 1965 and 1973 for Ibadan Station representing variabilities of high, low and moderate solar activities, respectively are used. Also used are the NmF2 variabilities of July 1970 and July 1971 (available data) for Ibadan, Singapore and Slough for the purpose of latitudinal comparison. Sunspot number, R, of July 1970 is 112.5, thus NmF2 variability of July 1970 represents NmF2 variability during high solar activity following the definition given by ITU-R (1997), R of July 1971 is 81.0 representing moderate solar activity by the same definition for the three epochs. Plots of NmF2 variabilities of March equinox, June solstice, September equinox and December solstice for Ibadan station with the hours of the day are shown in Fig. 1a-d.

In order to find out if high relative variability is the case at night because of low value of NmF2, absolute variability (standard deviation) of NmF2 is plotted with local time for March equinox only as shown in Fig. 2. Figure 3a-c show NmF2 variability of month by month NmF2 daily values in four bins of local time (00-05, 06-11, 12-17, 18-23 LT). The relationship between NmF2 variability at Ibadan with sunspot number is also considered for the four seasons. The plots of the correlation coefficient, r, with sunspot number, R, for the seasons are shown in Fig. 4. Latitudinal dependence of VR is sought by plotting the diurnal variation of NmF2 of VR of July 1970 and July 1971 for Ibadan, Singapore, Slough (Fig. 5a, b). In Fig. 6, is the plot of correlation coefficient, r between NmF2 VR and R for the three stations. Values of r are obtained from July relative variability and July sunspot number of the three stations for 1968-1971.

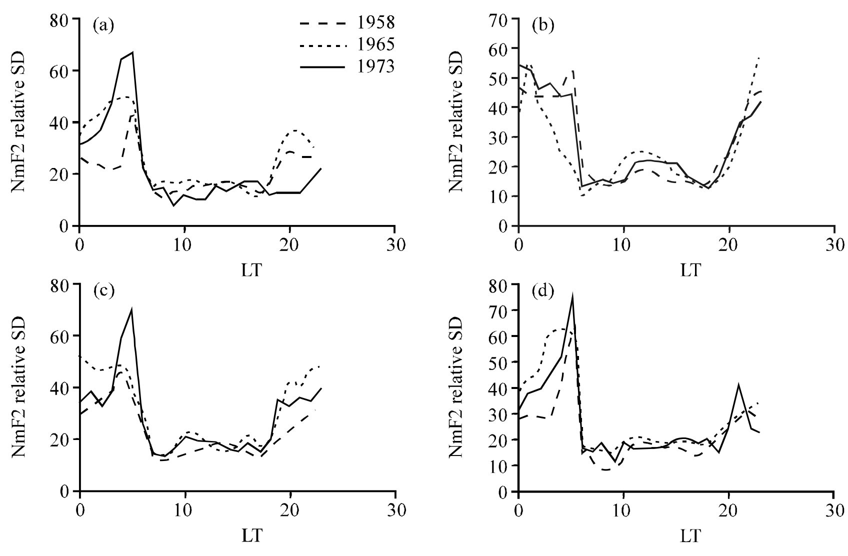

Fig. 1: Diurnal NmF2 relative variability of the equinoxes and solstices, (a) December solstice, (b) June solstice, (c) March equinox and (d) September equinox

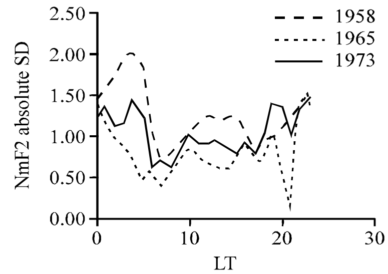

Fig. 2: Diurnal NmF2 (absolute vaviability) SD for March equinox

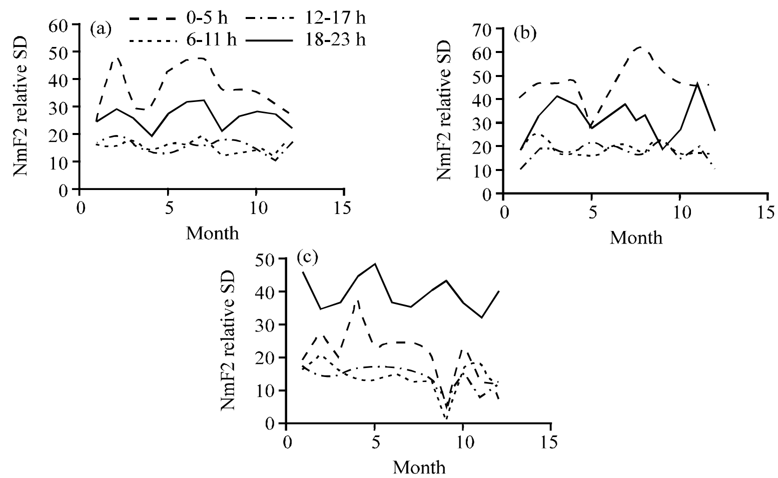

Fig. 3: Annual NmF2 relative variability of different LT bins for (a) 1958, (b) 1965 and (c) 1973, respectively

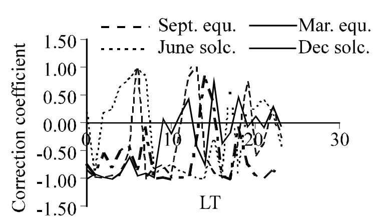

Fig. 4: Diurnal correlation coefficient between VR and R of Ibadan during equinoxes and solstices

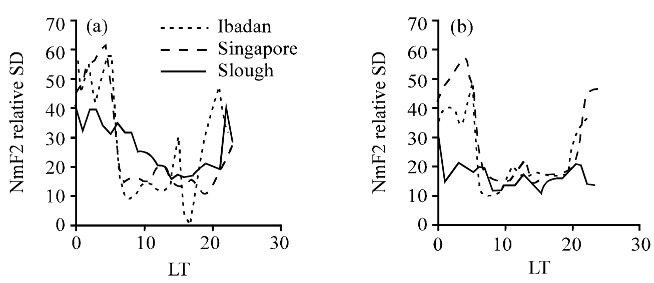

Fig. 5: Diurnal NmF2 relative variability Ibadan, Singapore and Slough during (a) 1970 and (b) 1971, respectively

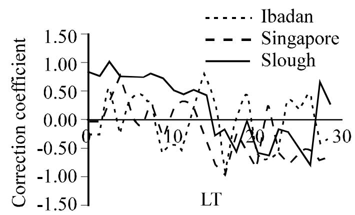

Fig. 6: Diurnal correlation coefficient between VR and R of Ibadan, Singapore and Slough

RESULTS AND DISCUSSION

Figure 1 shows that there are generally two major peaks in the relative variability, VR, of NmF2 at Ibadan for the three epochs of solar cycle-1958, 1965 and 1973. The peaks occurs an hour or two before dawn and an hour or more after dusk. What can pass as a minor peak also occurs at about noon. The present results which imply that VR is greater at night than during the day agrees with the results of Kouris and Fontiadis (2002), Bilitza *et al.* (2004) and Amarante *et al.* (2004). This is also shown in the Fig. 3 in which is illustrated relative variability for four bins of LT. Variability is higher for 00-05 h LT and 18-23 h LT bins. The present results do not however show minimum variability at midday as observed by Amarante *et al.* (2004).

No significant seasonal variation is observed for daytime VR during the three epochs of solar cycle (Fig. 1, 3). The afternoon seasonal difference in VR obtained by Bilitza *et al.* (2004) for Ouagadougou (12°N, 1, 8°W, dip 15.9°) is not obtained in this study. The difference in the present result and theirs is probably due to dip latitudinal difference in Ibadan (7.4°N, 3.9°E, dip 6°S) and Ouagadougou. Nighttime VR is observed to peak in September equinox and June solstice during 1958. During 1965, a year of low solar activity, the peak of nighttime VR occurred during the equinoxes while in 1973, a year of moderate solar activity, nighttime VR was maximum in September equinox (Fig. 1). Plots of VR for different LT bins during the three epochs, shown in Fig. 3 also indicate that VR of 00-05 LT and 18-23 LT bins (nighttime) is maximum mostly during the equinoxes. This is in good agreement with the result of Rishbeth and Mendillo (2001), who concluded that greater variability at equinox is inherent.

Figure 5a shows that daytime VR increases with latitude during high solar activity year of 1970 while the reverse appears to be the case at night. This result is in good agreement with that of Rishbeth and Mendillo (2001) though the present result is the case during high solar activity. No particular year is mentioned in this result of theirs among others though they used data of 1957-1990. During moderate solar activity year of 1971, no latitudinal difference is observed in day time VR (Fig. 5b). Nighttime VR is however greater for Singapore and least for Slough during this epoch. Comparisons of Fig. 5a and b show that daytime VR at Slough is about 50% higher during high solar activity than during moderate solar activity unlike the result of Rishbeth and Mendillo (2001), who found no difference during both epochs for Slough.

It is worth noting that VR at some hours of the day decreases with increase in solar activity, as represented by R, sunspot number and increases with R at other hours alternately. This is obvious from the diurnal plot of r, the correlation coefficient, between VR and R (Fig. 4). Thus the nighttime increase of VR with R and the reversal during the day mentioned by Bilitza *et al.* (2004) is not observed in the present result. Also the plot of correlation coefficient, r between VR and R in Fig. 6 shows that for Slough, VR increases with

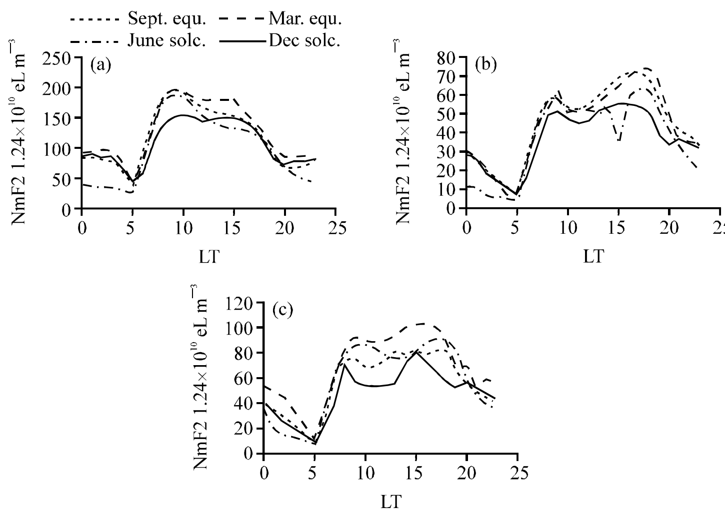

Fig. 7: The NmF2 of different seasons during (a) 1958, (b) 1965 and (c) 1973, respectively

R between 2200 and 1100 h and decreases with increase in R between 1200 and 2100 h. For Ibadan and Singapore, VR is observed to increase or decrease alternately with R [the same observation is made at all the seasons of 1958, 1965 and 1973 (periods of high, low and moderate solar activities, respectively) for the Ibadan station (Fig. 4)]. The difference in the nature of the correlation of VR with R between the latter stations, low latitude stations,and the mid latitude station of Slough could be latitudinal.

Bilitza *et al*. (2004) mentioned that relative VR is greater at night because of low value of NmF2 at these hours of the day. This can also be partly responsible for the minor peak around noon. As a result of noon-bite-out caused by E×B drift of ionization (Somoye, 2009). NmF2 noon values are lower than NmF2 values of hours just before and after noon. It is necessary to note that the absolute VR of NmF2 and not just the relative variability is actually high at night and also slightly high around noon. Figure 2, in which absolute VR (standard deviation) is illustrated against LT for March equinox, as example, shows that absolute VR is actually high during the night and a little high around noon. Thus the other cause of VR being high at night and around noon could be as a result of decay in NmF2 at these hours and decay leads not only to reduction but also to irregularity in the magnitude of NmF2. Rishbeth and Garriot (1969) pointed out that NmF2 decreases rather irregularly at night. This can be extended to the noon time when there is depletion of NmF2 on the equatorial and low latitude areas.

That there is no significant seasonal trend in daytime VR could be because there is little or no difference in the daytime values of NmF2 from 6-15 h of the different seasons. Figure 7a-c lend credence to this. It is however, rather curius that nighttime VR of the equinoxes are greater than those of the solstices, NmF2 mean values being lower at the latter than the former.

The alternate increase and decrease of VR with R at different hours of the day seem to be an anomaly since it is expected that VR will generally decrease with R. From the Eq. 1, as R increases the reciprocal of NmF2 increases. That this is not so is due to the anomalous nature of F2 layer.

CONCLUSION

Absolute variability (and not just relative variability) is generally high during the night than during the day. It is also a little high around noon than other daytime hours.

No significant seasonal variation is observed for day time variability. Night time variability is higher during both equinoxes or during one of the equinoxes and June solstice depending on the epoch of solar cycle. Daytime VR which is not observed to show latitudinal difference during moderate solar activity appears to increase with latitude during high solar activity. In the night time it decrease with latitude. NmF2 variabilities of Ibadan and Singapore are observed to increase or decrease with R alternately at different hour of the day. At Slough, NmF2 variability is observed to increase with R during about the first half of the day and to decrease with R in the later part.

REFERENCES

Amarante, G.M., M.C. Santamaría, M.M. de González, S.M. Radicella and R. Ezquer, 2004. Day-to-day changes in experimental electron density profiles and their implications to IRI model. Adv. Space Res., 34: 1878-1886.

Bilitza, D., O.K. Obrou, J.O. Adeniyi and O. Oladipo, 2004. Variability of foF2 in the equatorial ionosphere. Adv. Space Res., 34: 1901-1906.

ITU-R, 1997. HF Propagation Prediction Method, Recommendation. International Telecommunication Union, Geneva.

Kouris, S.S. and D.N. Fotiadis, 2002. Ionospheric variability: A comparative statistical study. Adv. Space Res., 29: 977-985.

Rishbeth, H. and O.K. Garriot, 1969. Introduction to Ionospheric Physics. Academic Press, New York.

Rishbeth, H and M. Mendillo, 2001. Patterns of F2-layer variability. J. Atmos Solar Terrs Phys., 63: 1661-1680.

Somoye, E.O., 2009. Periodicity of solar cycle from diurnal variations of foF2 at Ibadan. Int. J. Phys. Sci., 4: 111-114.