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Full Length Research Paper

Investigation of electron density variation in some regions of the Ionosphere at Nsukka, Nigeria

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The variations of electron density in some regions of the ionosphere at Nsukka (6.50°N and 7.2°E) in Nigeria were investigated. The dependence of these variations on the 11 year solar cycle, seasonal changes, diurnal and altitude effects were analysed. The results of the analyses reveal that the electron density concentration in the ionosphere is dependent on heights. Our results also confirm the non-existence of the sun's ionizing radiation at night in this region. It has been found that the electron density variations in Nsukka are of 11 year solar cycle. The years of high solar activities correspond to high electron density in Nsukka, while the years of low solar activities are also years of low electron density. Consequent to the findings from this study, it was found that in Nsukka electron density variations are higher in months of April and September, implying that electron densities attain maximum value during this period. The observed trends in electron density variations in the ionosphere at Nsukka may be attributed to the solar control of the ionosphere.

Key words: Electron density, magnetic variation, solar activity.

INTRODUCTION

The ionospheric electron density variation under different conditions has a very vital role to play in understanding the lower as well as the upper atmosphere. The ionosphere is strongly coupled to other regions like the magnetosphere and interplanetary space, whose states affect activities on earth. Signals transmitted for communication and navigational purposes from satellite must definitely pass through the ionosphere, which acts as a perturbing medium on satellite-based navigation systems (for example. density global positioning system). One very important propagation effect is the phase and amplitude scintillation caused by irregularities in electron density distribution. The various impacts of ionospheric electron density variations on man and his system compel Nigeria researchers to actively participate in many aspects of both theoretical and observational studies concerned with the state of the ionosphere.

Works of Taylor (1971) and Adeniyi et al. (2001) showed that electron concentration varies with height and that various reaction and processes taking place in the ionosphere resulted in it being stratified into layers. Liu (2006) showed the existence of seasonal and latitudinal dependences of solar activity variations on electron density in the east Asia/Australia sector.

Sato et al. (1969) reported increase in electron density at a height of 1000 km at polar latitudes. Results of Danilov et al. (2001) confirm the existence of a positive relation between electron density and temperature, while Tereshchenko et al. (2002) showed that the average electron density is greater in summer than in autumn.
However, Pandey (1996) in comparing the IRI 90 model with the incoherent scatter radar at Arecibo points out that generally, IRI overestimates electron densities. On the other hand, Decker et al. (1997), using Jicamarca incoherent scatter radar revealed that at low-latitude, during the day-time the observed profile shape can be much broader in altitude than that specified by IRI-90, while at night, just after sunset, observed F_2 peak altitudes are significantly higher than what is specified by IRI-90.

Danilov (2006) created an empirical model of the D region within the auroral oval using rocket measurements of the electron concentrations at high-latitude rocket sites

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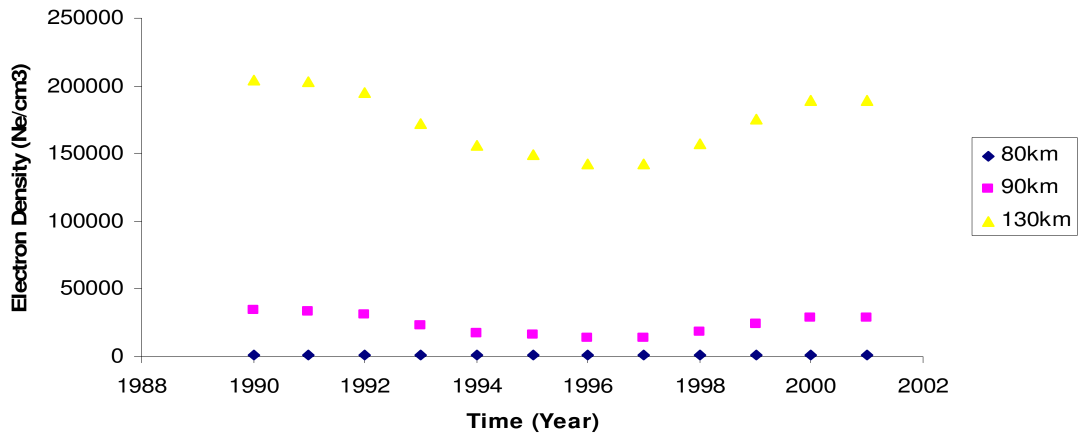

Figure 1. Yearly electron density variation at 12 noon.

both in the Southern and Northern hemispheres and the empirical formulae derived described the electron behaviour.

The present study investigated the electron density variations in some regions of the ionosphere at Nsukka, Nigeria, where no such work has ever been carried out in the past, with a view to obtaining information on the nature of these variations. The dependence of these variations on seasonal and diurnal changes and on altitude was also investigated.

Source of data and method of measurement

The data analysed in this work were obtained from IRI version 2005. The prerequisite input parameters used for retrieval of these data were; year (1990 - 2000), month (January - December), day (1 - 31; dependent on month duration), time (local time; 12 noon and 12 midnight), coordinate (geographic), latitude (6.5^0 N), longitude (7.2^0 E), height (65, 80, 90 and 130 km).

The data covers an eleven year period, that is, one solar cycle. Hence the days encompass both geomagnetic quiet and disturbed days. The procedure was wholly repeated for the 11 year period under investigation and the output was given as a function of one user-selected independent variable.

Analyses of Results and Discussion

Both the day and night time values of the yearly electron density from 1990 - 2000 (one solar cycle) at different heights were analysed. From the analysis, a comparison of annual variations and altitude dependence of ionospheric electron density was made. The effects of solar activities on the electron density in the ionosphere around the study area were ascertained.

Plots of yearly electron density variation in Nsukka during daytime and nighttime at different altitudes are seen in Figures 1 and 2.

Figure 1 depicts an almost constant density of electron throughout the period under study at a height of 80 km. At 90 km, electron density peaked in 1990 at a value of 3424 cm^{-3} and gradually decreased to 13624 cm^{-3} in 1997. The concentration of electron density becomes quite remarkable at a height of 130 km, with distinct yearly variation throughout the solar cycle. At this height, electron density measures 204413 cm^{-3} at the onset of the solar cycle (that is, in 1990) and towards the completion of the cycle, the density of electron is recorded as 189037 cm^{-3}. It has been observed generally that at these altitudes, electron density was on the decline from 1991 downward, with minimal values recorded in 1997. Nonetheless, there was an increase following the completion of the cycle.

Figure 2 shows electron density variation at midnight for the eleven-year period at various altitudes. At 85 and 90 km, electron density remains at 248 and 473 cm^{-3} respectively throughout the period under investigation. In contrast, at 130 km, electron density fluctuates in similar pattern to observations made during daytime with maximum electron density of 1024 cm^{-3} in 1990. This decreeses steadily to 438 cm^{-3} in 1997, peaking once more at 842 cm^{-3} in the year 2000. Starting from 1997, the electron density increased gradually, reaching a peak in the year 2000, at the various heights of 80, 90 and 130-km.

This result is in agreement with that obtained by Tereshchenko et al. (2002). These variations of electron density with height are attributed to various reactions and processes taking place in the ionosphere.

A remarkable trend is observed in night time at height range of 85 - 90 km, where the electron density remains constant. This feature is inferred to be caused by the absence of the sun's ionizing radiations, hence reduction of solar control. The minimal ionization observed could be

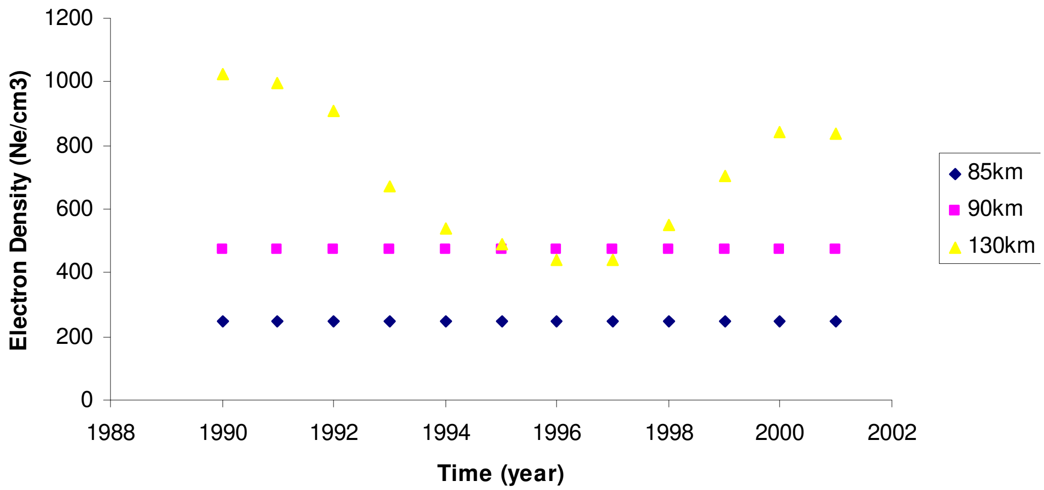

Figure 2. Yearly electron density variation at 12 midnight.

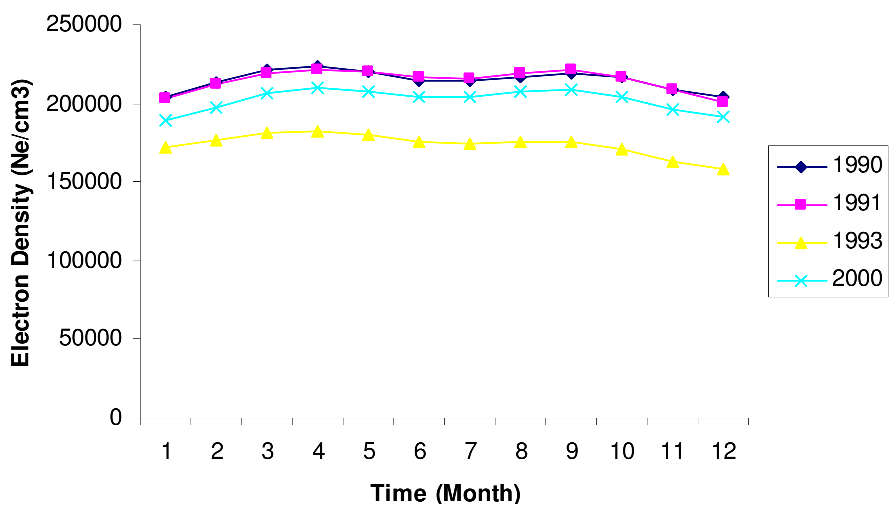

Figure 3. Monthly variation of electron density at 130 km at 12 noon.

due to cosmic ray particles from extragalactic activities. The enhanced electron density with increasing solar activity and time variation as generally observed is consistent with studies (Bremer et al., 1976; Danilov, 2007, 2008) and is attributed to significant enhancement of absorption during high solar activities. As shown in Figure 1 and 2, higher concentrations of electron were recorded in 1995 and 1996 for all heights considered in this study.

The plot for monthly variations in Nsukka features electron density exhibiting a twelve-month cycle with two maxima in April and September respectively. This feature was observed at 130 km in all 11 years under investigation (Figure 3). This is in accordance with the results obtained by Bailey et al. (2000), where maxima occur conspicuously in the daytimes than in nighttime Large maxima occur persistently at noon and conversely minima at midnight as evidenced in Figures 4 to 6. At approximately 01:00 Local Time (LT), the electron density initially at about zero, progressively increases with time to a steep rise at 12:00 LT, where a maximum is reached. Subsequently, the electron density sharply declines till about 18:00LT with a continued but almost a zero value throughout nighttime. Several works (Tereshchenko et al. 2002; Adeniyi, 2004; Pérez-de-Tejada 2004; Lakshmi, 1997; Gwal et al., 2004) report same zero and decreased electron density variation at post-midnight.

Furthermore, electron density at Nsukka is generally higher both at nighttime and daytime in years of high solar activity than in years of low solar activity. This characteristic is clearly obvious from Figures 4, 5 and 6 with

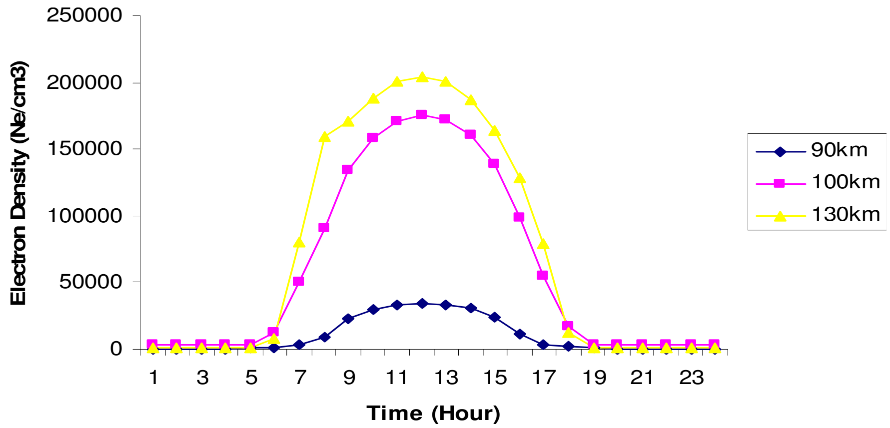

Figure 4. Hourly electron density variation in 1990.

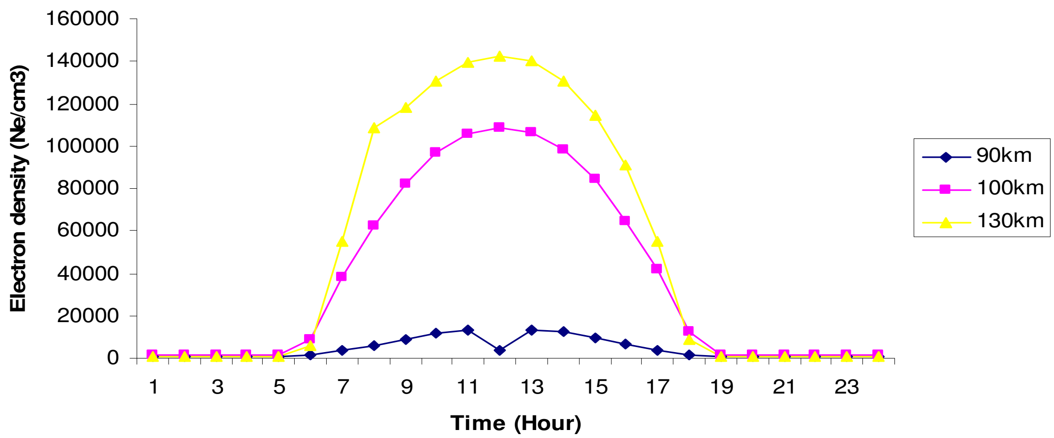

Figure 5. Hourly electron density variation in 1996.

electron concentration of 210 x 10^3 cm^{-3} at noon in a typical year of high solar activity (1990), while the electron density for 1996 (a year of low solar activity) at noon was just 140 x 10^3 cm^{-3}.

Conclusion

The result of the study reveals that the electron density variations at lower atmosphere at Nsukka are primarily controlled by solar radiation at different seasons and altitudes. In general, very high values of electron density were recorded at noon, while very low values were recorded at night or early morning hours. The highest values were observed during the months of April and September confirming results of Tereshchenko et al. (2002). This could be attributed to solar intensity variations. It was also noted from our study that electron density increases during the years of high solar activity and reverse is the case for years of low solar activity, further confirming works of Danilov, (2007); (2008); Bremer et al. (1976).

Since the refractive index of the ionosphere is dependent on both frequency and ionospheric electron density, probably, the effects of radiation are greater at low frequency. We ascertained from this study that during the months of April and September operating frequency of radio signals should be increased for avoidance of risk of information loss.

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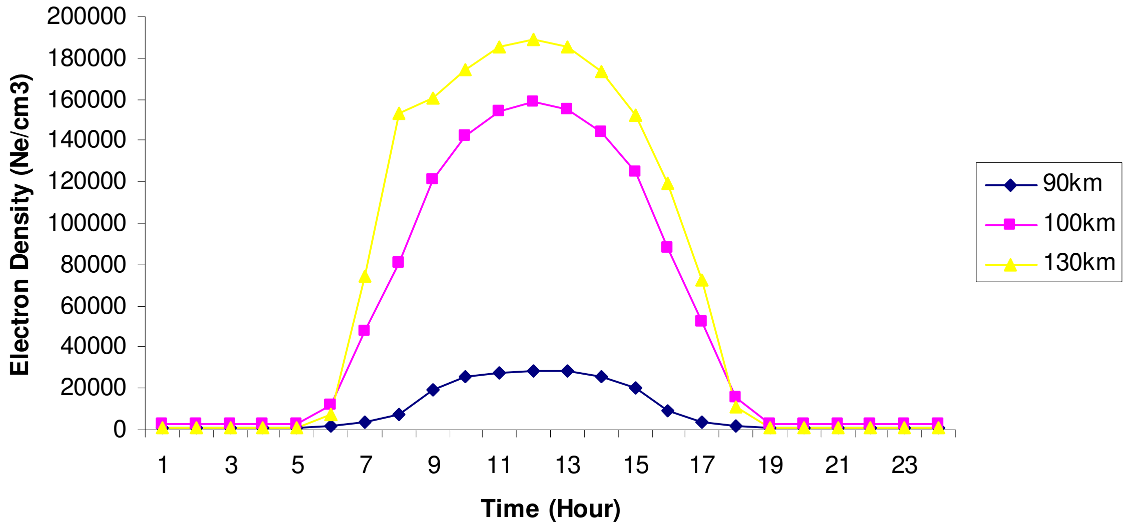

Figure 6. Hourly electron density variation in the year 2000.

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