QUASI-PERIODIC OSCILLATIONS IN THE VARIABILITY OF THE HEIGHT OF THE MAXIMUM IONOSPHERIC PLASMA DENSITY AND THE IONOSPHERIC VERTICAL PLASMA DRIFTS NEAR THE EQUATOR

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ABSTRACT

We use Fourier transform method to obtain spectra characteristics structures of the observed ionospheric peak height (h_mF_2) and vertical $\overline{E}\times\overline{B}$ drifts determined from model calculation and virtual height (h'F); in the equatorial region. Our data were collected from Ibadan and spans from January to December 1958 (IGY-year), a year of high solar activity maximum. Our results demonstrate several wave components. The strongest wave amplitude in h_mF_2 spectra range from about 23 km to a value near 30 km, whereas $\overline{E}\times\overline{B}$ drifts is between 3.53-5.53 m/s. Overall, clear 2.4-day and 3.2-day oscillations are shown in the vertical plasma drifts and h_mF_2 spectra respectively.

1 INTRODUCTION

The middle and upper atmosphere encompasses the earth atmosphere ranging from (about 10-500 km) in altitude. It is the critical layer linking the solar and terrestrial system. The tidal waves and gravity waves are well-known in this region, planetary waves (hereafter referred to as PWs) effects on the F-region ionosphere at the equatorial region of the African continent remains relatively badly studied, especially experimentally. This is because there is acute shortage of ionospheric station at the equatorial region in the African sector. The most fundamental ionospheric parameters that are valuable in the specification and prediction of the ionospheric F_2 region structure, and that can be used for various ionospheric models, and transionospheric propagations models are height of the peak density and vertical plasma drifts [1,2,3]. The main purpose of this study is to present detailed spectral characteristics of peak height (h_mF_2) of ionospheric F_2 region and vertical electrodynamic drifts at various conditions.

2 DATA

Our database consists of hourly vertical sounding ionospheric data collected from Ibadan, Nigeria (7.4^{0}N, 3.9^{0}E; dip: 6^{0}5) during 1957/58 International Geophysical Year (IGY), a year of high solar maximum, with mean Zurich sunspot number, R_z = 185. In order to calculate vertical drifts, Five-day records from January to December 1958 during daytime quiet-period were picked for the analysis. Days chosen from these five quiet days are those with ionograms good enough to be scaled manually following [4] five-point analysis method. Magnetic storm days were avoided. Average profiles on an hourly basis for each of the month chosen were calculated from these 5 days. Election densities were then deduced at F-region heights.

It can be shown from electron density continuity equation that simplified daytime (from 0600 to 1800 LT) vertical electromagnetic plasma drift velocity model, applicable in the vicinity of the geomagnetic equator, valid away from the peak, is given by:

$$V_z = \frac{H_p(h)q(h,\chi)}{N_e(h,t)} - H_p(h)\beta(h) \quad (1)$$

where $H_p(h)$ is the plasma scale height, a function of height, $q(h,\chi)$ is the electron production rate, both function of altitude and solar zenith distance, χ estimated from Chapman theory [5], $N_e(h)$ is electron density at height h obtained from ionograms, $\beta(h)$ is electron loss rate, which is height-dependent obtained from [6]. Notice that all the parameters in Eq.1 are each function of altitude. The rapid lifting of the F-layer precedes the occurrence of plasma irregularities during the nighttime as seen by spread-F in the ionograms, which does not allow the determination of the electron density profiles in this period. The nighttime vertical drifts values given in this study is therefore estimated from the time rate of change of h'F, virtual height of the bottom-side of F region, $\Delta h'F/\Delta t$. The calculations were made for both quiet and disturbed periods.

The data sets for both peak height (h_mF_2) and vertical drifts are split in the subsets representing daytime and nighttime conditions, magnetically quiet and disturbed times. During quiet-period, the Kp indices were smaller or equal to 3, whereas during the disturbed-time the Kp indices were grater than 3. Furthermore, Fourier transforms are then used to generate spectra characteristics structures of h_mF_2 and V_z, and the results are smoothed by the Hanning Window function.

3 RESULTS

In this section, we present short-term fluctuations of the height of the maximum ionospheric plasma density and the vertical plasma drifts near the geomagnetic equator. Figure 1 (panels a to d) displays the spectral structures of h_mF_2. In plot 1a, three distinct spectral peaks are observed, with periods 11, 23 and 34-hour respectively. Their amplitude decreases systematically. Fig. 1b shows smooth variation with only one visible component occurring at the high frequency region. Fig. 1c indicate one strong component at about 12-h is shown. Another one weak component is also seen. During the nighttime and disturb condition (panel d), the fluctuation is strong nonetheless components are observed. It appears that smooth variations are observed during the nighttime (panels b and d).

Fig. 1 also indicates that he strongest wave amplitude range from about 23km to values as large as near 30km, with maximum amplitude seen during the quiet nighttime. Overall, 3.2-d oscillation is shown in the h_mF_2 data.

Figure 2 (panels a to c) shows vertical drifts spectra at Ibadan. Only one remarkable component at 12-h period is seen during the quiet daytime. It appears that the entire spectral shapes in Fig. 1 (plots b and c) exhibit similar periodicities. Spectra peaks at periods 12-h, 24-h, and 36-h are evident including terdiurnal (8-h tide). Plot 2(c) shows double-peak structures at 12-h and 36-h peaks. The vertical drifts during the nighttime sums to be sensitive to influences from above and below the ionosphere. Also, the range of maximum amplitude of oscillation in the vertical drifts is found between about 3.53-5.53 m/s with maximum occurring during quit-daytime. A clear 2.4-d is manifest in the vertical drifts data.

From Figures 1 and 2, planetary wave activities are significantly higher during the nighttime than the daytime sector. Wave activities during geomagnetically disturbed conditions are approximately 18% higher than that of quiet time condition in h_mF_2 data, but wave activity during geomagnetic quiet-time is just about 8% greater than disturbed-time in the vertical drifts data. More extensive experimental and numerical studies are clearly needed to understand the relative important of the different sources of these fluctuations.

The data presented above clearly indicate large fluctuations in h_mF_2 and vertical drifts. There are several potentially important sources that are causing the variations during magnetically quiet and active times and also during the daytime and nighttime sectors. Our results are consistent with the results reported by [7]. [8] pointed out that quiet-time ionospheric variability is probably associated with irregular day-to-day variations due to short-term changes in tidal forcing, the effects of planetary waves and irregular winds in the dynamo region, and changes in the dynamic conditions at the base

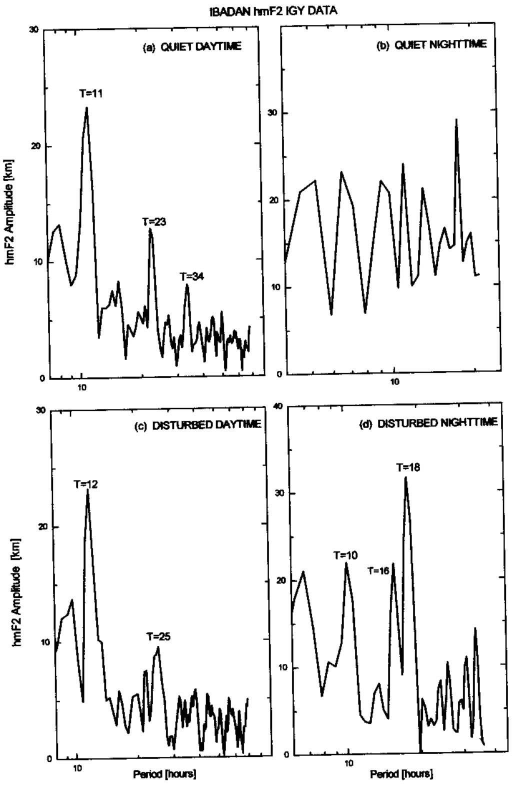

Fig. 1. Spectra structures of peak height of F2 layer for:quiet-daytime, quiet-nighttime, disturbed-daytime and disturbed nighttime conditions under high solar flux.

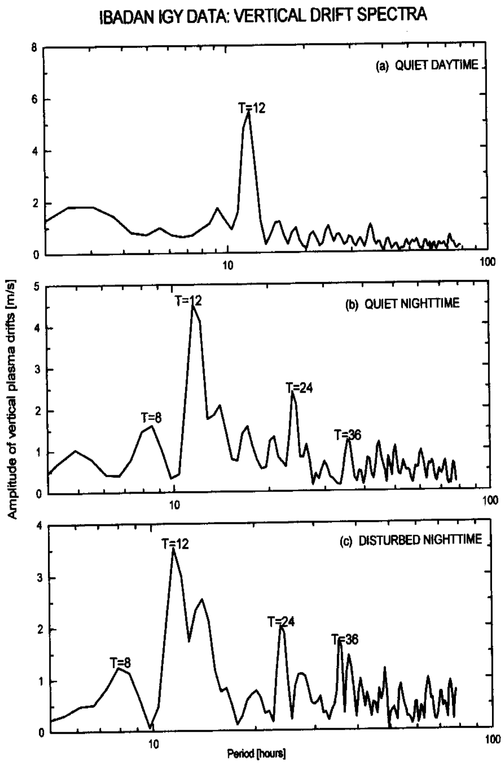

Fig. 2. Ibadan vertical drifts spectra during high solar activity for daytime and nighttime conditions and for quiet and disturbed times.

of the thermosphere. According to[9], tides generated in the troposphere and stratosphere propagate into the lower thermosphere, dissipating their energy at 100-150km altitude, thus releasing considerable amounts of momentum and energy into the region. [10] reported clear 5-day periods on the midlatitudes irregularities, while [11] found that the most commonly observed periods appear in two preferential bands i.e., the 2 to 3 day and the 4 to 6 day band. We believe that planetary waves are also responsible for the short-term quasi-periodic oscillation in the h_mF_2 and vertical plasma drifts.

Finally, we have established that the variability of the ionospheric F-region may be tightly connected with planetary wave forcing from the lower atmosphere. Nonetheless, extra observational and modeling studies are certainly essential.

REFERENCES

[1] R. Bent, J.R. Lepofsksy, S.K. Liewellyn, and P.G. Schmid, "Ionospheric range-rate effect in satellite-to-satellite tracking", *Operational Modeling of the Aerospace Propagation Environment*, vol. 1, (Eds.) H. Soicher, AGARD Conf. Proc., 230, pp. 9-15, 1978.

[2] B.G. Fejer and L. Scherliess, "On the variability of equatorial F-region Vertical plasma drifts", *J. Atmos. Terr Solar Phys.*, vol. 63, pp. 893-897, 2001.

[3] C.G. Fesen, "Lower atmosphere/thermosphere/ionosphere coupling due to tides", 2nd IAGA/ICMA Workshop, *Vertical Coupling in the Atmosphere-Ionosphere System*, July 12-15, 2004, Bath, UK, pp. 26.

[4] J.M. Kelso, "A procedure for the determination of the vertical distribution of the electron density in the ionosphere", *J. Geophys Res.*, vol. 57, pp. 357-367, 1952.

[5] S. Chapman, "The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth", *Proc. Phys. Soc., London*, 43, pp. 26-45, 1931.

[6] J.A. Ratcliffe and K. Weeks, "*The ionosphere, in physics of the upper atmosphere*", Academic press, New York, 1960.

[7] E.S. Kazimirousky, "Coupling from below as a source of ionospheric variability – a review", Ann. *Geophys*., 45, pp. 1-29, 2002.

[8] A.D. Richmond, "The ionospheric wind dynamo: effects of its coupling with different atmospheric regions", In: Johnson, R.M., Killeen, T.L. (Eds.), T*he upper Mososphere and lower Thermosphere*, American Geophysical Union, Washington, DC. 1994.

[9] H. Rishbeth, R.A. Heelis and I.C. F. Muller-Wodarg, "Variations of thermospheric composition according to AE-C data and CIIP modeling,", *Ann. Geophys*., 21, pp. 1-12, 2003.

[10] R.T. Tsunoda, M. Yamamoto, Ks. Igarashi and S. Fuka, "Quasi-periodic radar echoes from midlatitudes sporadic-E and role of the 5-day planetary wave", *Geophys. Res. Lett*., 25, pp. 951-954, 1998.

[11] M. Voiculescu, C. Haldoupis and K. Schlegel, "Evidence for planetary wave effects on midlatitudes backscatter and sporadic E-layer occurrence", *Geophys. Res. Lett*., 26, pp. 1105-1108, 1999.