THE IMPACTS OF THE EQUATORIAL PLANETARY WAVES ON THE UPPER IONOSPHERE

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ABSTRACT

We present spectra structures of the critical frequency of the F_2 region (f_oF_2) and F2- region vertical drifts (V_z), over the period January to December 1958 (IGY-era), a year of solar maximum; using ground-based ionospheric data obtained from Ibadan. Our results exhibit different behaviors. 12-hour tide appears to be a persistent feature of the equatorial atmosphere. 8-hour tide is also apparent. The average wave amplitude is found to be about 4.52 MHz and 4.53 m/s in f_oF_2 and V_z respectively. In addition, a long period oscillation of ~ 2.5-day, ~12-day is found in V_z and f_oF_2 data in that order.

1 INTRODCTION

The most fundamental ionospheric parameters are the F_2 region critical frequency, f_0 F_2 and F_2 region vertical plasma drifts, V_z. The global variations of these quantities are used in the specification and prediction of the structure F_2 region [1]. The F_2 region at equatorial and low latitudes is a fascinating part of the upper atmosphere, which apart from its academic interest has an applied value in radio communications [2]. The equatorial plasma drifts and critical frequency of F_2 layer exhibit large variability at different time scales. Several recent studies suggest that planetary waves play an important role in the electrodynamics of the lower thermosphere [3]-[5]. Unfortunately, the effects of planetary waves on ionosphere in the equatorial region of African continent are relatively less investigated. In the thermospheric and ionospheric heights, a part of wave activity can be created in-situ as primary (e.g., diurnal tide, gravity waves of auroral origin) as secondary waves (e.g., some gravity waves) but a large fraction is due to vertical propagation of waves from the lower thermosphere. In this paper, we study spectral characteristics of, f_oF_2 and vertical electrodynamic drifts (V_z). We also estimate the dominant planetary wave periodicities present in the data.

2 DATA TREATMENT AND METHOD OF ANALYSIS

Our database consists of hourly vertical sounding ionospheric data collected from Ibadan, Nigeria (7.4^0N, 3.9^0E; dip: 6^05) 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 quiet daytime 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. Average profiles on an hourly basis for each of the month chosen were calculated from these 5 days. Electron 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

$$V_z = H_p q / N_e - H_p \beta \tag{1}$$

where H_p is the plasma scale height, q is the electron production rate, estimated from Chapman theory [5], N_e is electron density obtained from ionograms, β is electron loss rate 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.

Data for both critical frequency of F_2 layer (f_oF_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 f_oF_2 and V_z, and the results are smoothed by the Hanning Window function.

3 RESULTS

The top panels in Fig. 1 give the spectral structures of F2-region critical frequency (f_0F_2) during the quiet ($Kp \leq 3.0$) daytime and nighttime conditions. The bottom panels in the other hand display the disturbed ($K_P \geq 3.0$) daytime and nighttime conditions. The observed peaks are labeled to assist knowing the periodicity of the peak. Notice that several peaks are found in the high frequency region corresponding to period 24 to 72 hours. The well-defined peaks with harmonics are dearly evident. Fig. 1. indicates that the f_0F_2 data analyzed have nearly similar periodicities (panels a, b, and c). The amplitudes of the peaks exhibit diffuse-peak structure (panels a, b, and d). The average amplitude of the peaks is about 4.53 MHz. The lowest amplitude of the peak is found during the quiet-nighttime period, with a value of about 2.86 MHz; whereas, the maximum value of the peak amplitude is just about 6.70 MHz during disturbed-nighttime condition. Besides the dominant tidal periodicities, there is often weaker components oscillation (e.g. 8-hour terdiurnal oscillation) present as well. A long period of approximately 12-day is found in the Equatorial Ionization. Anomaly (EIA). This is consistent with the results reported by [8].

Figure 2 shows the results of spectra structure of vertical drifts during quiet daytime (panel a), quiet nighttime (panel b), and disturbed nighttime (panel c) respectively.

Results indicate sharp peaks. One dominant peak at 12-hour period is observed during the quiet daytime, with amplitude 5.53 m/s (panel a). In panel b and c in Fig. 2, we found a very similar pattern of periodicity in the spectrum with periods at 8, 12, 24 and 36-hour respectively. Double-peak structure is also observed during disturbed nighttime condition, with 12-hour period. In addition, the amplitude of the strongest component is 4.53 and 3. 53 m/s in quiet nighttime and disturbed nighttime respectively. The average amplitude is about 4.53m/s. Vertical drifts oscillation with period near 2.5-d is observed.

Thus, our spectra results presented above clearly indicate significant fluctuations in vertical drifts and f_0F_2 data at F_2-region. [9] Reported that planetary waves contribute significantly to the variability of MLT winds. Tides generated in the troposphere and stratosphere propagates into the lower thermosphere, dissipating their energy at 100-150 km altitude, thus releasing considerable amounts of momentum and energy into the region [10]. [11] 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 dynamic region, and changes in the dynamic conditions at the base of the thermosphere. The results of the present study aim to give a better understanding of the problem of the EIA's long period oscillation. Also our results must help to improve the ionosphere modeling effort by providing data from a station close to the magnetic equator, a region of the African low-latitude ionosphere with relatively few observations.

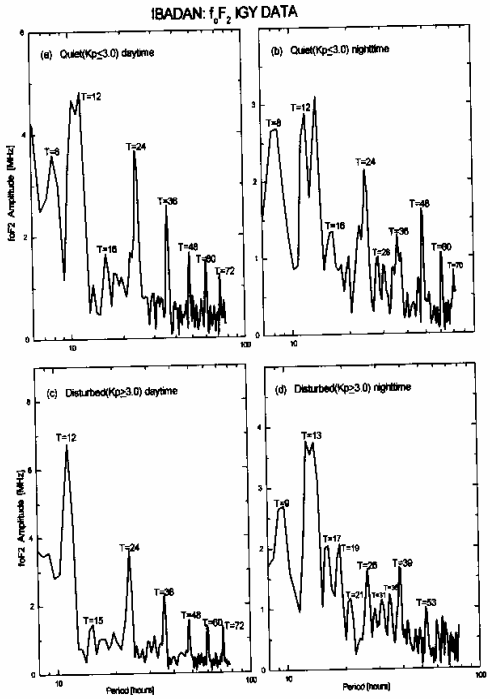

Fig. 1. Spectral structures of F2 region critical frequency(foF2) for low and high geomagnetic activity conditions and for daytime and nighttime sectors during solar maximum.

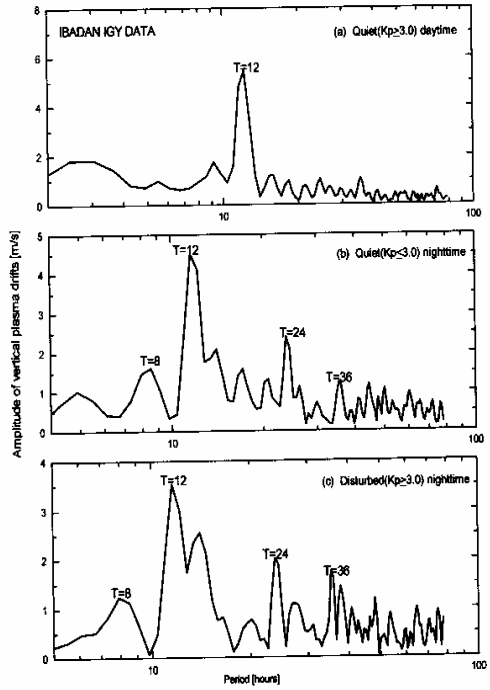

Fig. 2. Ibadan vertical drifts spectra during high solar activity for daytime and nighttime conditions and for quiet and disturbed times.

ACKNOWLEDGEMENT

The authors thanks Mrs. Inge Lievens at URSI Headquarter at Gent, Belgium for making this work to be in final form.

REFERENCES

[1] C.M. Rush, M. Pokempner, D.N. Anderson, J. Perry, F.G. Stewart, and R. Reasoner, "Maps of foF_2 derived form observation and theoretical data," *Radio Sci.,* vol. 19, pp. 1083-1097, July-August 1984.

[2] G. Rajaram, "Structure of the equatorial F-region, topside and bottomside-a review," *J. Atmos. Terr. Phys*., vol. 29, pp. 1125-1144, 1977.

[3] P.R. Chen, "Two-day oscillation of the equatorial ionization anomaly," *J. Geophys. Res*., vol. 97, pp. 6343-6348, 1992.

[4] J.M. Forbers. and S. Leveroni, "Quasi 16-day oscillation in the ionosphere" *Geophys. Res. Lett*. vol. 19, pp. 981-986, 1992.

[5] H.F. Parish, J.M. Forbes, F. Kamalabadi, "Planetary wave and solar emission signatures in the equatorial electrojet, "*J. Geophys. Res*., vol. 99, pp. 355-361, 1994.

[6] J.M. Kelso, "The calculation of ionospheric electron distributions" *J. Atmos. Terr. Phys*., vol. 10, pp. 103-109, 1952.

[7] L. Chapman, "The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth", *Proc. Phys. Soc.*, vol. 43, pp. 26-45, pp. 484, 1931.

[8] L.Yi and P. Chen, "Long period oscillations in the Equatorial Ionization Anomaly correlated with neutral wind in the mesosphere, "*J. Atmos. Terr. Phys*., vol. 55, pp.1317-1323, 1993.

[9] E.S. Kazimirovsky, "Coupling from below as a source of ionospheric variability: a review," *Ann. Geophys*, vol. 45, pp. 1-29, 2001.

[10] H. Risbeth, R.A. Heelis and I.C.F. Muller-wodarg, "Variation of thermospheric composition according to AE-C data and CIIP modeling," *Ann. Geophysicae,* vol. 21, pp. 1-12, 2003.

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