International Journal of Physical Sciences Vol. 4 (3), pp. 111-114,March, 2009
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Periodicity of solar cycle from diurnal variations of f_0F_2 at Ibadan

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Accepted 26 February, 2009

Some features of diurnal variations of f_oF_2 are found to show a better response of solar activity impact than the hourly means of diurnal variation over a sunspot cycle. The ionization build-up-rate and the difference in pre- and post-noon peak are found to give 11- year periodicity for Ibadan (7.4˚N, 3.9˚E, 6˚S dip) station while the hourly means are observed to give different periodicities. There is however, a phase lag between these features that is, build-up rate of ionisation and the difference in post- and pre-noon peak of ionisation on one hand and the sunspot number on the other hand. The morning depression rate and evening decline do not however show solar cycle trend. For Singapore the solar cycle trend of ionisation build-up-rate and pre- and post noon peaks is slight while for Slough (51.5˚N, 359.4˚E, 66.5˚S dip) another station investigated for similar results, the ionisation build-up-rate, difference in post-and pre-noon peaks, morning depression rate and evening decline do not show any solar cycle trend. No solar cycle trend is observed in morning depression rate and evening decline for Singapore (1.3˚N, 103.8˚E, 17.6˚S dip).

Key words: Diurnal, build-up-rate, periodicity, phase-lag.

INTRODUCTION

The periodicity of solar cycle is generally accepted to be 11 years by many workers such as Misra et al. (1971), Ratcliffe (1970), Oyinloye and Onolaja (1977), Somoye (2005) to name a few. Observation of foF2 hourly average values, over many years however shows that the solar cycle periodicity of f_oF_2 is not consistently 11 years at all the hours of the day. At some hours the solar cycle periodicity of f_oF_2 hourly average is as low as 8 years while in some it is as high as 14 years (Figure 1).

It is the aim of this paper to point out that (i) some features of diurnal variation of f_oF_2 hourly average values are better indices of solar cycle periodicity. Such features are the ionization build-up-rate (defined in section 2) and the difference in pre-noon and post-noon peak values of ionization (ii) 1957 and 1968 are consecutive maximum years of effect of solar activity on the ionosphere as oppose to 1958 and 1969 for solar activity given by sunspot numbers.(iii) consequent upon (ii) is that there is a phase lag in the response of the ionosphere to solar activity and solar activity(iv) latitudinal dependence is observed for ionisation build-up-rate and difference in pre-noon and post-noon peak of diurnal variation of f_oF_2.

EXPERIMENTAL SET UP, DATA AND METHODOLOGY

Critical frequency of F2 layer, f_oF_2, readings were obtained using the union radio mark 2 recorder type ionosonde developed at the Radio Research Station in Slough. Its transmitter and receiver are two separate subunits kept in tune by a frequency sensitive servo system as the transmitter frequency is swept over the range 0.7 to 25 MHz in a sweep time of five minutes duration. The sounder sends out pulses at a repetition rate of fifty per second with a peak power of up to one kilowatt. The photographic records of variation of virtual height with frequency called ionograms give the critical frequency values.

Observations of the ionisation build-up-rate and those of the difference between pre-noon and post-noon peak of the diurnal variation of f_oF_2 hourly average values are obtained for Ibadan (7.4˚N, 3.9˚E, 6˚S dip), Singapore (1.3˚N, 103.8˚E, 17.6˚S dip), and Slough (51.5˚N, 359.4˚E, 66.5˚S dip) stations.

The values of the ionization build-up-rate are obtained by finding the quotient of the difference between the pre-

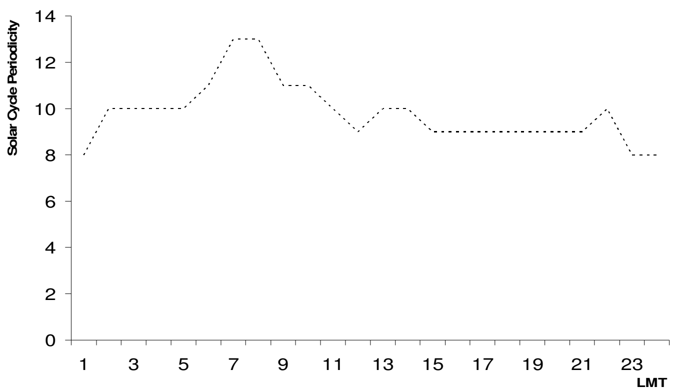

Figure 1. Illustrating variation of solar cycle periodicity.

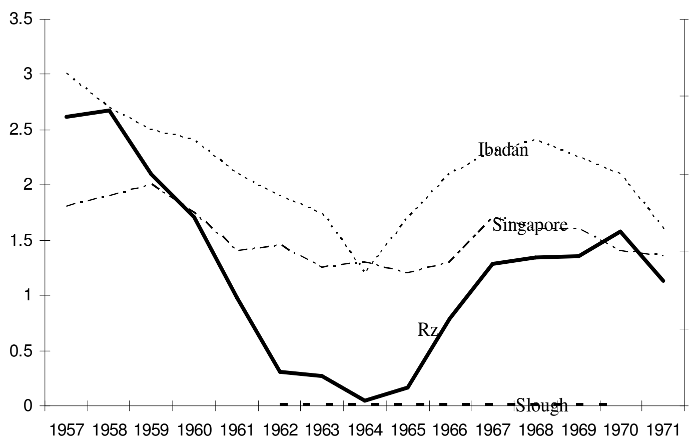

Figure 2. Illustrating build-up rate of ionization and sunspot number, Rz.

noon peak (which usually occurs between 0900 and 1000 h) and the pre-dawn depression (usually at about 0500 h) of average f_oF_2 diurnal variations and the time interval. For the difference between pre-noon and post-noon peaks the values are obtained by simple subtraction.

Average values of foF2 for July 1957 to 1971 are used for the Ibadan (7.4˚N, 3.9˚E, 6˚S dip) and Singapore stations (1.3˚N, 103.8˚E, 17.6˚S dip). Average values of foF2 for July 1957 to 1962 are not available for Slough station (51.5˚N, 359.4˚E, 66.5˚S); the values used are those of July 1963 to 1971.

The plots of ionization build-up-rate with years and that of the difference in pre-noon and post-noon peaks are shown in Figures 2 and 3, respectively. Also shown on both figures are the plots of sunspot numbers, Rz for July 1957 to July 1971.

RESULTS

The Ibadan station results (Figure 2) show that the build up rate of ionization is maximum during 1957 indicating a phase lead between build up rate and sunspot activity which maximum occurred in 1958 i.e. during IGY. The rate reduces till 1964 after which it picks up, getting to another maximum during 1968. The build up rate of ionisation follows this trend slightly for Singapore (1.3˚N, 103.8˚E, 17.6˚S dip) and not at all for Slough (51.5˚N, 359.4˚E, 66.5˚S).

The difference in peaks of diurnal variation shown in Figure 3 is also found to show solar cycle trend with the highest value occurring for the 1957 diurnal variation at Ibadan. The value is on the decrease, getting to a negative value of -0.5 for 1964 (Negative value indicates that the pre-noon peak is lower than the post-noon peak). The value picks up again getting to a maximum of 1.6 for 1968 diurnal variations. Solar cycle trend is not observed in the difference of post-noon and pre-noon peaks for the ionospheric station of Slough. Figure 3 shows that this value has a slight solar cycle trend at Singapore, another low latitude station.

No solar cycle trend is observed in rate of morning depression and evening decline for the three stations.

DISCUSSION

Ionization build-up-rate is dependent on the intensity of the ionizing radiation and the zenith angle of the sun's radiation. The zenith angle is known to increase until noon after which it reduces at any location in the earth. Also the intensity of the ionising radiation increases as sunspot number increases.

The difference in pre-noon and post-noon peak of ionization, which exists as a result of noon-bite-out is positive during the period of high sunspot number due to the vertical drift of ionization occurring a little after noon, at which period the electrojet current is maximum (Umoh and Adeniyi, 1995) The electrojet current gives rise to the electric field, E which is responsible for the E×B force causing the drift. B is the earth's magnetic field. The vertical drift occurring a little after noon makes the post-noon peak smaller than the pre-noon peak during periods of high sunspot number. Conversely, during period of low sunspot number the vertical drift of ionisation occurs a little earlier than noon when the electrojet current is maximum resulting in the pre-noon peak being smaller than the post-noon peak.

The vertical drift of ionization in the F2-layer is controlled by both the meridional thermospheric winds and the E×B force (Maeda, 1977; Rishbeth and Garriot, 1969). The meridional thermospheric winds are caused by pressure gradients due to atmospheric density and temperature variation over the earth at about 120 km (Kohl et al., 1968).

Latitudinal dependence of ionisation build-up-rate is obvious from the dependence of ionisation partly on the zenith angle of the ionising radiation which reduces as the latitude increases. That the difference in pre-noon and post-noon peak is latitudinally dependent can be explained thus. The vertical drift of ionisation causing this

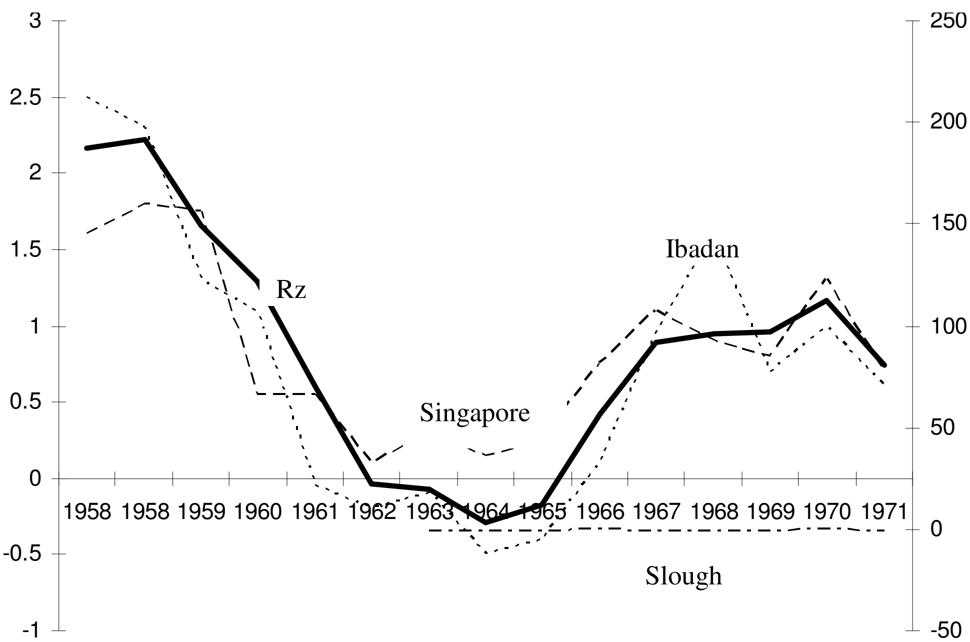

Figure 3. Illustrating difference in pre-noon peak and post-noon peak of ionization and sunspot number, Rz.

difference is more pronounced in the narrow region of about ±5˚magnetic dip where geomagnetic field lines are almost horizontal in which case electric charge is not allowed to leak away to other latitudes (Rajaram, 1977).

The solar cycle trend observed in the build-up-rate of ionization and difference in pre-noon and post-noon peaks offer a way of finding the time lag of the effect of solar activity on the ionosphere as well as the exact periodicity of solar cycle of ionospheric parameters.

In these results, 1957 and 1968 are shown as the years of maximum ionospheric response to solar activity in the month of July at Ibadan implying a periodicity of 11 years. This indicates a phase lead of 1 year over sunspot numbers which are found to be maximum in the month of July 1958 and July 1969. In Figure 2, a phase lead of 1 year is observed for ionisation build-up-rate over Rz, sunspot number. The same phase lead of 1 year is observed for difference in pre-noon and post-noon peak over Rz (Figure 3). Phase lead or phase lag has been reported, by some workers, between sunspot numbers and values of ionospheric parameters. Okunola (1984), in his studies of the variation of sunspot numbers with foEs reported a phase lag of about 2 years of sunspot numbers over foEs for Ibadan. Kotadia (1962) observed a phase lead of the occurrence of peak values of foEs over maximum sunspot number. Rao and Rao (1966) found that the maximum of equatorial sporadic E, Es, occurred a year before sunspot maximum in some cases whereas it occurred one year after sunspot maximum in other cases. The former agrees with the present result of sunspot maximum lagging behind ionization build-up-rate and the difference between pre-noon and post-noon peak.

Conclusion

(i) Ionization build-up-rate and the difference between pre-noon and post-noon peaks are two features of diurnal variation that not only show solar cycle trend but are also better indices of solar cycle periodicity than hourly averages of diurnal variation at the Ibadan station (7.4˚N, 3.9˚E, 6˚S dip).

(ii) Solar cycle trend of ionization build-up-rate and the difference between per-noon and post-noon peaks is slight for Singapore (1.3˚N, 103.8˚E, 17.6˚S dip) and nil for Slough (51.5˚N, 359.4˚E, 66.5˚S dip).

(iii) These results indicate latitudinal dependence of ionization build-up-rate and the difference between pre-noon and post-noon peaks.

(iv) No solar cycle trend is observed for rate of morning depression and evening decline at the three stations

(v) Sunspot number, Rz is observed to lag behind ionization build-up-rate and the difference between pre-noon and post-noon peak by 1 year in each case for the equatorial station of Ibadan.

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