ASSET Series B (2002) 1 (2):1-8
ISSN 1595-9694

SOLAR CYCLE EFFECT ON THE VARIATION OF SOME IONOSPHERIC E - AND F- REGION PARAMETERS AT IBADAN

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ABSTRACT

The effect of solar cycle on the variation of the virtual height (h^l) and critical frequency (f_o) of echoes of ionospheric E- and F2- region at Ibadan were investigated. While the median virtual heights of 1965 (low epoch of solar cycle) and 1970 (high epoch of solar cycle) were used for both regions, the median critical frequency of 1964 (low epoch) and 1971 (high epoch) were used.

It was found that these parameters for both regions varied differently with solar cycle. The variations of h^l_{F2} and f_{oF2} were however greater than those of h^l_E and f_{oE} were found not to vary much with solar cycle, the rate of hourly change of h^l_E being 7.5 km/h during 1965 and 7 km/hr during 1970. The rate of yearly change was 14 km/hr. Also the diurnal curves of f_{oE} during 1964 and 1971 were similar that the slight differences between them were not noticeable. These results indicate uniform changes in both parameters of the E region over a solar cycle. On the other hand, not much similarity is observed in the diurnal curves of f_{oF2} of 1964 and 1971. Also, the rate of diurnal change of h^l_{F2} is 11 km/hr and 17 km/hr during 1965 and 1970 respectively. The rate of yearly change for h^l_{F2} is 26 km/year. These results indicate non-uniform changes in both parameters of the F2 region over a solar cycle. This may be due to the complex nature of the F2 region.

Harmonic analyses carried out show that the diurnal component is predominant over the semi-diurnal components of the parameters for both regions while the solar cycle components are predominant over the semi-cycle components of all the parameters.

Key words: Solar cycle, Variation, E- and F- region

INTRODUCTION

The virtual heights, h^l, at which signals are reflected from the ionosphere, vary as the radiation, which produces the ionization and is responsible for the reflection of signals.

The rate of production of electrons per unit volume, q, in the ionosphere is a function of height, h, the intensity, I, of the incident radiation and the zenith angle, X, i.e.

$$q = B \cos X \frac{dI}{dh}$$

where, B is the number of ions produced in a unit volume of absorbed radiation. The solar cycle variation differs for different ionospheric parameters and from place to place. It is desirable to know how the virtual height of the reflection of E- and F- region echoes, h^l_E and h^l_{F2} as well as the critical frequencies (f_{oE} and f_{oF2}) at which the signals are reflected vary with solar cycle at Ibadan (3.9°E, 7.45°N, Dip 5.8°S).

ANALYSIS

In order to eliminate seasonal variation, diurnal curves of h^{I}_{E} and h^{I}_{F2} median values of March during 1965 and 1970 years of low epoch and high epoch respectively of solar cycle are considered and illustrated in Figures (1) and (2). Also diurnal curves of f_{oE} and f_{oF2} of 1964 (a year of low epoch of solar cycle) and 1971 (a year of high epoch of solar cycle) are considered and illustrated in figures (3) and (4). The choice of solar cycle years of 1965 and 1970 for h^{I}_{E} and h^{I}_{F2} and 1964 and 1971 for f_{oE} and f_{oF2} is due to availability of data.

The plots of 1200 (LMT) median values of h^{I}_{E} and h^{I}_{F2} during the month of March (1965 to 1975) and those of 1200 hours median values of f_{oE} and f_{oF2} during the month of March from 1964 to 1974 are also illustrated in Figures (5) and (6). Median values were used since they were readily available in the ionospheric bulletins and because median values of ionospheric parameters have been found to show no significant difference from corresponding mean values Somoye (1984).

Harmonic analyses were carried out on the diurnal variations of h^{I}_{E} and h^{I}_{F2} of 1965 and 1970 as well as on the diurnal variations of f_{oE} and f_{oF2} of 1964 and 1971. Harmonic analyses are also performed on the solar cycle variations of h^{I}_{E}, and h^{I}_{F2}, f_{oE} and f_{oF2}.

Variation of h^{I}_{E} and h^{I}_{F2}

The median value of h^{I}_{E} was observed to increase from 0700 hours to 1800 hours during 1965 with a rate of 7.5 km/h (Fig. 1). During 1970, the increase of h^{I}_{E} median value was from 0600 hours till 1300 h (a rate of 7 km/hr) before reaching a stable daytime value (Fig. 2). The rate of increase was about the same for 1965 and 1970, years of low and high epochs of solar cycle respectively.

During 1965, h^{I}_{F2} median value was observed to increase from 0600 h to 1100 h with a trough at 1400 h between two maxima that occur at 1100 h and 1900 h. The rate of increase was 11 km/h (Fig.1). A fairly steady increase was observed from 0600 h to 1800 h during 1970 with a rate of 17 km/h (Fig. 2). The solar cycle variation of h^{I}_{F2} was more pronounced than that of h^{I}_{E} was 14 km/year (Fig. 5). The troughs observed in the solar cycle variation illustrations were due to the eclipse of 1971.

Harmonic analyses results (Table 1) reveal that the diurnal component redominates the semi-diurnal components during 1965 and 1970 for both h^{I}_{E} and h^{I}_{F2} as expected, while the solar cycle component is predominant over the semi-solar cycle component, also as expected.

Variation of f_{oE} and f_{oF2}

The diurnal variation of f_{oE} during 1964 and 1971 (years of low and high epoch of solar cycle) is illustrated in Fig. 3. The curves, both of which peaked at 1200 h appear symmetrical at the same time of the day and are so similar that the slight differences are not noticeable. This implies little or lack of variation of f_{oE} with the epochs of the solar cycle. The yearly median values of f_{oE} (Fig. 6) are observed to be uniform.

The diurnal variation curves of f_{oF2} median values during 1964 and 1971 (years of low and high sunspot numbers) do not show much similarity (Figs. 3 and 4). The only similarity observed was in the rise of the median values in both curves from 0600 hours to 0900 h. Higher values were observed during 1971 than during 1964, a consistent result with that of Dieminger (1959) working at the high latitude station of Lindau (52°N).

Harmonic analyses results (Table 1) show that the diurnal component is predominant over the semi-diurnal component for both f_{oE} and f_{oF2} during both epochs of solar cycle. The solar cycle component also predominate the semi-solar cycle component for both f_{oE} and f_{oF2} (Table 2).

Table 1. Results of harmonic analysis for diurnal variations at high and low epoch of solar cycle

Layers			Diurnal components	Semi-diurnal components
E layer during Low Epoch	f_{oE}	Amplitude (MHz)	1.01	0.35
		Phase (^{o})	81.47	-6.2
	h^{l}_{E}	Amplitude (km)	39.75	6.74
		Phase (^{o})	93.36	45.66
E layer during High Epoch	f_{oE}	Amplitude (MHz)	2.5	0.07
		Phase (^{o})	-0.9	-10.6
	h^{l}_{E}	Amplitude (MHz)	63.98	33.90
		Phase (^{o})	151.89	60.90
F2 Layer during Low Epoch	f_{oF2}	Amplitude (MHz)	0.19	0.08
		Phase (^{o})	40.10	-69.3
	h^{l}_{F2}	Amplitude (MHz)	39.2	24.2
		Phase (^{o})	58.93	84.36
F2 Layer during High Epoch	f_{oF2}	Amplitude (MHz)	0.18	0.07
		Phase (^{o})	14.7	-10.6
	h^{l}_{F2}	Amplitude (MHz)	91.1	53.95
		Phase (^{o})	2.17	64.79

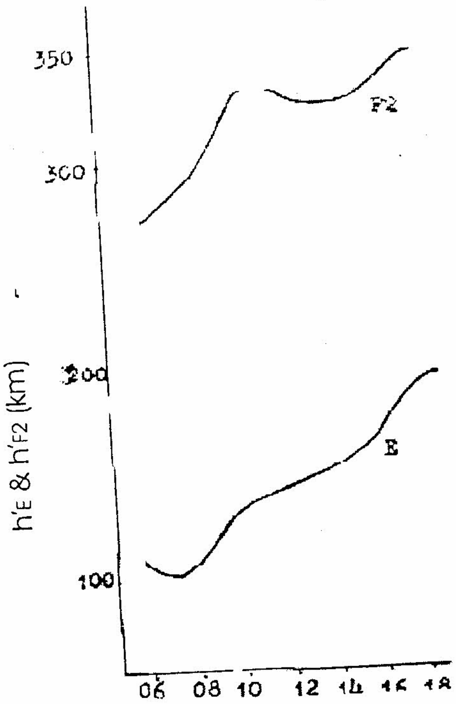
Table 2. Results of harmonic analysis for solar cycle variation at 1200 (LMT)

Layer			Solar cycle component	Semi-solar cycle component
E	f_{oE}	Amplitude (MHz)	0.14	0.09
		Phase (°)	-52.10	-86.96
	h'_E	Amplitude (MHz)	46.98	11.01
		Phase (°)	115.44	172.80
F2	f_{oF2}	Amplitude (MHz)	1.12	0.74
		Phase (°)	-48.6	33.48
	h'_{F2}	Amplitude (MHz)	95.57	11.71
		Phase (°)	115.24	3.28

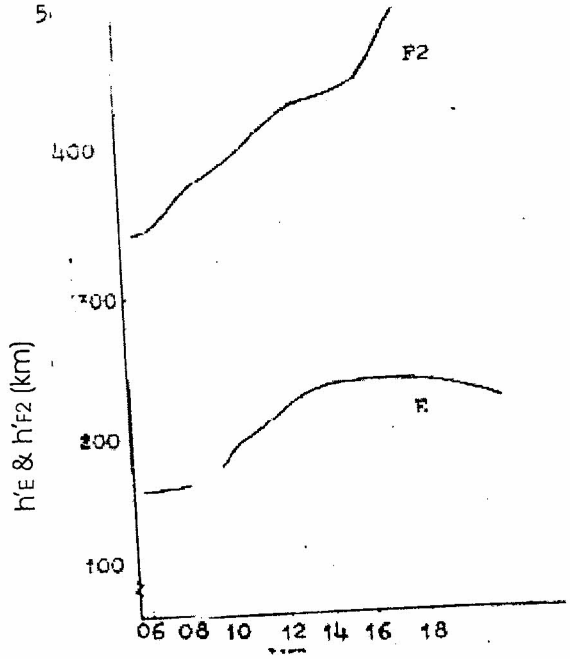
DISCUSSION

Sizes of irregularities of ionospheric F2 layer at Ibadan have been observed by Bamgboye (1969) and Somoye (1997) to be significantly greater during years of high sunspot numbers than their extent during years of low sunspot numbers. Martyn (1959) observed that F2 irregularities are enhanced when the layer moves up. The F2 layer is raised during years of high solar activity (Olatunji, 1966). The similarity in the trend of h'_{F2} results presented above and those of Bamgboye (1969) and Somoye (1997) on sizes of F2 layer irregularities confirm the causal relationship between the rate of increase of virtual height of reflection of echoes and the irregularities of the F2 layer. Also, the higher the level of reflection, the higher the frequency of signal to be reflected at that level. When the F2 layer is raised, which is the case during high sunspot numbers, f_{oF2} median values are expected to be greater during high epoch than during low epoch of solar cycle. This is consistent with the higher value of critical frequency observed during high epoch of solar cycle than during low epoch in the present result for the F2 layer. Dieminger (1959), at Lindau (a high latitude station) also obtained higher f_{oF2} values during the period of high sunspot numbers than during the period of low sunspot numbers.

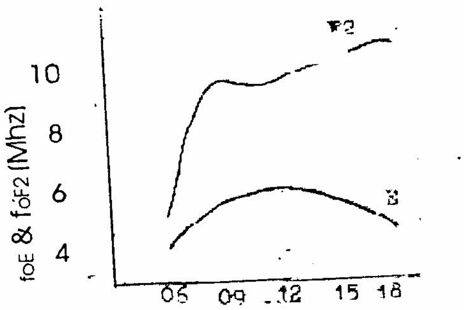
The present results for the E region which show that the diurnal variation of h'_E and that of f_{oE} is the same during the period of minimum solar activity as well as during the period of maximum solar activity is consistent with other E region parameters considered by Onolaja and Oyinloye (1977) who made the same observation for E region drift of irregularities and Somoye (1999) who considered fading rates of E region echoes.



LMT
Fig 1. Diurnal variation of h'E & h'F2 during 1965



LMT
Fig. 2. Diurnal variation h'E & h'F2 during 1970



LMT
Fig 3. Diurnal variation of h'E & h'F2 during 1964

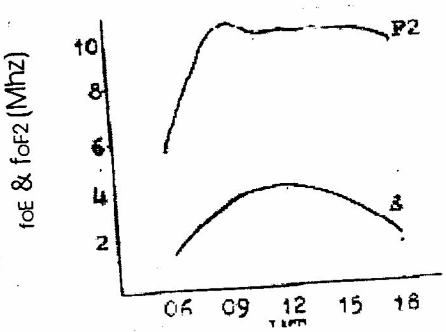


Fig 4. Diurnal variation of foE & f,f2 duing 1971

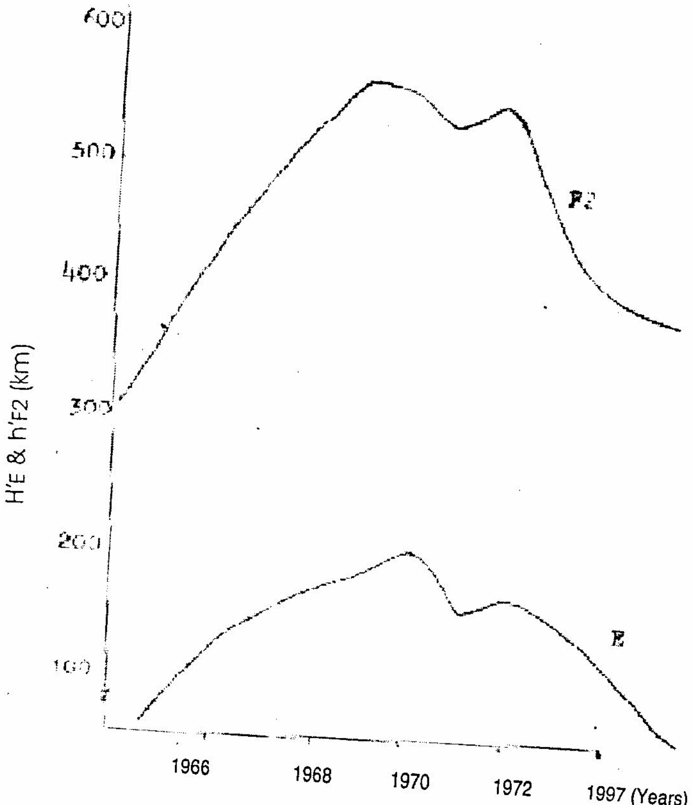


Fig 5. Solar cycle variation of h'E & h'F2 at 12h (LMT)

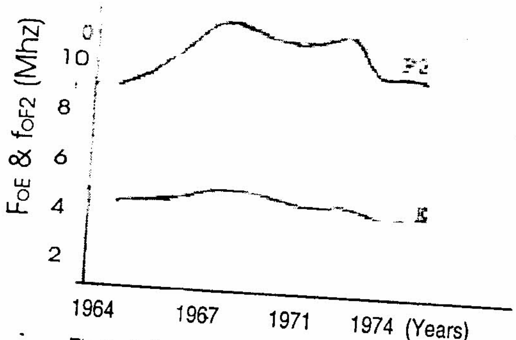


Fig 6. Solar cycle variation of f_{oE} & f_{oF2} at 12 h (LMT)

No observation has been made on relationship between the virtual height of the reflection of echoes of E layer, h^{l}_{E}, and the sizes of irregularities of the E layer. E layer irregularities are not observed to vary significantly with solar cycle (Bamgboye, 1969; Somoye, 1997). That h^{l}_{E} diurnal variation is the same during maximum and minimum values of solar cycle is an indication that hourly median values of h^{l}_{E} vary at the same rate (uniformly) for each year of the epoch.

On the other hand, that solar cycle variation is observed for h^{l}_{F2} yearly median values and for the hourly median values of h^{l}_{F2} implies that a non-uniform variation takes place in the hourly median values of h^{l}_{F2} for each year. The non-uniform variation of h^{l}_{F2} and f_{oF2} hourly median values and by extension those of other ionospheric F2 parameters may not be unconnected with the complex nature of the F2 layer which may be due to instability in solar radiation when it get to the F2 layer. The solar radiation might have become stable by the time it reaches the E layer.

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