Reprinted from Vol. 10, No. 1 (1959) of the Indian Journal of Meteorology and Geophysics, Pages 69 to 72

551.594.12

Annual Wave in the world-wide F-Region Ionization

B. N. BHARGAVA

Kodaikanal Observatory, Kodaikanal

(*Received 5 June 1958*)

ABSTRACT. An analysis of squares of noon median F2 layer critical frequencies for a 3-year period has been made in order to derive the latitude variation of the annual effect in the electron densities and its relation to average F2 layer ionization. The results indicate that the annual component R_1 varies with the latitude in a manner very nearly similar to that of the steady ionization R_0 and that for a given value of R_0 for any latitude, R_1 can be derived approximately from a linear relationship of the type $R_1 = 0 \cdot 3\ R_0 - 4 \cdot 5$. A similar analysis of 9-year data for precise phase and amplitude of the annual component for a pair of stations yields a value of R_1 which is of the same order of magnitude as R_0 and which attains a maximum around the epoch of minimum sun-earth distance.

1. Introduction

The non-season behaviour of F region ionization is well-known and several workers have found that there is a tendency for the occurrence of relatively higher ionization in December-January than in June-July in both the northern as well as the southern hemisphere. For instance, Berkner and Wells (1938) showed that after removing the effect of secular change the ionization had, superimposed on it, two components, namely, the seasonal 'out-of-phase' and the annual 'in-phase' components. From their analysis of data from Washington, Watheroo and Huancayo, Seaton and Berkner (1939) found that the 12-month waves at the three stations were in the same phase. Eckersley's (1940) analysis of several years' data indicated that the amplitudes of the annual wave was independent of the solar activity. To the contrary, Mambo (1957), from a study of data from 1947 to 1953, obtained a variation of amplitude of the annual component with increasing and decreasing solar activity. In this paper the variation of the annual component with geographic latitude has been obtained utilizing three years' data from 31 stations. From data extending over a period of 9 years at two of these stations, precise values of amplitudes and phases of the annual and semi-annual components have also been determined.

2. Analysis

Thirtyone stations all over the world, from which median values of noon critical frequency were available from CRPL F-series bulletins, were grouped into 19 pairs of stations, each pair consisting of a station in the northern and a station in the southern hemisphere at approximately the same geographic latitude. The squares of the monthly critical frequencies for each one of the two stations were averaged in order to eliminate possible effects due to local summer or winter. In order to restrict the secular changes due to solar activity to a minimum, a three-year period centered around sunspot minimum of 1953-54 was selected and the means for each one of the pairs were further averaged over the three-year period July 1952 to June 1955. The final averages were subjected to harmonic analysis and the amplitudes and phases of first two harmonics were derived. Similarly, for one of the pairs, *viz.*, Washington and Watheroo, 9-years' data were similarly analysed and precise values of the amplitudes and phases of the first three harmonics were derived.

3. Results and Discussion

Average ionization R_0 and the amplitudes R_1 and R_2 and phases t_1 and t_2 of the first and second harmonics respectively are given in Table 1 for each pair of stations together with the mean latitude of the pair.

TABLE 1

No.	Station North	Station South	Mean latitude	R_0 $(Mc/sec)^2$	R_1 $(Mc/sec)^2$	t_1 (months)	R_2 $(Mc/sec)^2$	t_2 (months)
1	Panama Canal Zone	Huancayo	10·7	64	9·0	10·7	15·5	2·9
2	Kodaikanal	Huancayo	11·1	52	9·5	10·6	7·9	3·2
3	Madras	Huancayo	12·5	56	11·3	10·6	8·5	3·2
4	Bombay	Townsville	19·1	78	14·1	10·9	9·9	3·0
5	Maui	Townsville	20·0	69	18·2	11·6	13·0	3·0
6	Maui	Rarotonga	21·0	76	28·6	11·5	17·8	3·0
7	Okinawa	Johannesburg	26·2	62	13·8	11·4	14·3	3·0
8	Okinawa	Brisbane	26·9	59	14·5	11·5	13·8	2·9
9	Yamagawa	Watheroo	30·7	46	6·7	11·6	8·4	2·9
10	White Sands	Cape Town	33·2	42	9·6	11·5	6·2	3·1
11	Washington	Watheroo	34·5	36	7·2	10·7	3·9	2·5
12	Tokyo	Canberra	35·5	41	7·0	10·1	8·0	2·9
13	San Francisco	Canberra	36·4	36	7·9	11·6	2·5	2·5
14	Schwarzenburg	Hobart	44·8	32	4·6	11·1	3·2	3·7
15	Graz	Hobart	45·0	32	3·2	10·9	2·4	3·7
16	Slough	Falkland I.	51·6	36	6·6	10·9	6·7	2·9
17	Adak	Falkland I.	51·8	36	8·0	11·1	7·6	3·0
18	Reyjavik	Port Lockroy	64·4	24	2·6	10·7	5·3	3·1
19	Baker Lake	Port Lockroy	64·6	23	2·6	10·7	3·7	2·8

TABLE 2

Pair of stations	R_0	R_1		R_2		R_3	
		Amplitude $(Mc/sec)^2$	Date of maximum	Amplitude $(Mc/sec)^2$	Date of maximum	Amplitude $(Mc/sec)^2$	Date of maximum
Washington and Watheroo	70	14·6	2 January	10·8	12 March and 12 September	2·0	12 February, 12 May and 12 August

The variation of R_0 and R_1 with latitude is plotted in Fig. 1 from which it will be seen that the annual component varies with latitude considerably and this variation is practically similar to that of R_0. The principal maxima for both are in the region of latitude of 15° to 25° and subsidiary maxima of small amplitude in the region of 50° to 55°. A plot of R_1 against R_0 (Fig. 2) shows considerable scatter especially for higher values of R_0 but still it indicates a linear relation of the type

$$R_1 = 0{\cdot}3\, R_0 - 4{\cdot}5$$

The correlation coefficient between R_0 and R_1 has been found to be 0·79, and that between R_1 and R_2 is 0·755.

The amplitudes and dates of maxima of the first three harmonics from analysis of 9-year data of Washington and Watheroo are shown in Table 2. It has been found that the first two harmonics represent about 97 per cent and the three harmonics represent about 99 per cent of the variance. The amplitude of R_1 is comparable with that of R_2. It will also be seen that R_2 has maxima on 12 March and 12 September, *i.e.*, in the period between the dates when the earth's

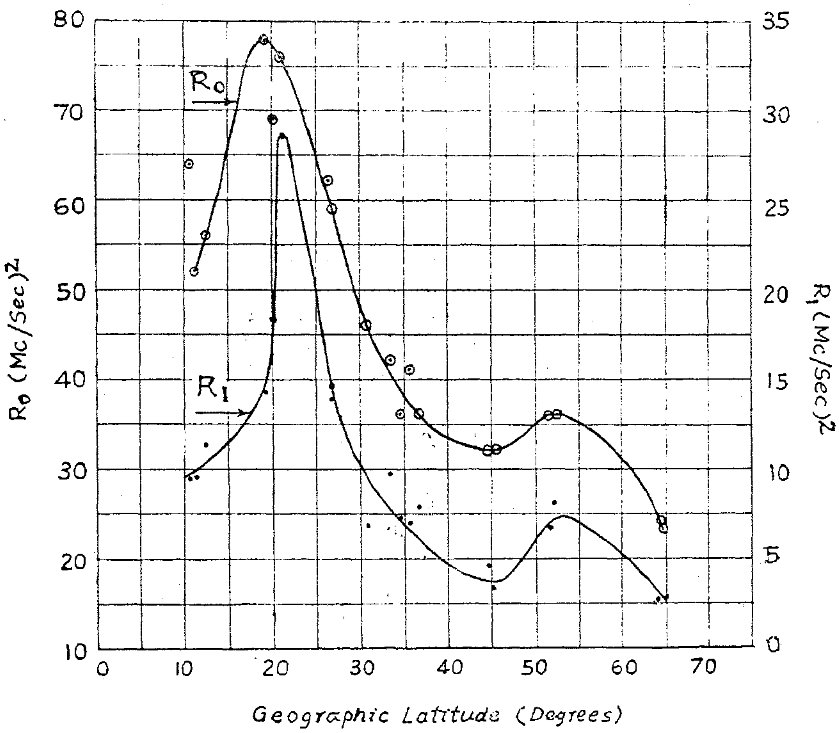

Fig. 1. Variation of R_0 and R_1 with latitude

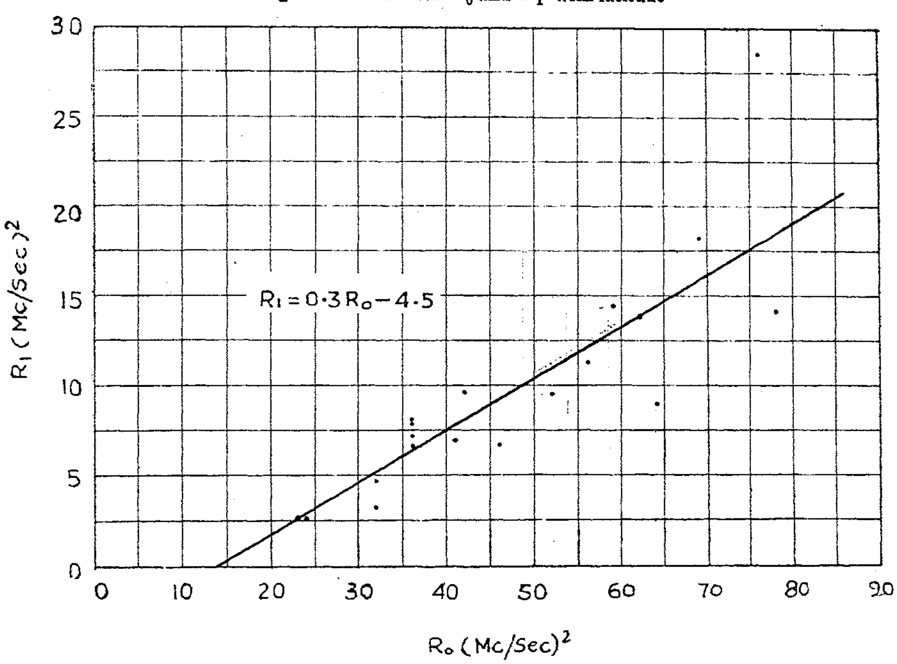

Fig. 2. Plot of R_1 against R_0

heliographic latitude is maximum (6 March and 8 September) and the spring and autumnal equinoxes (21 March and 23 September). Several workers have explained that this behaviour is associated with the earth's heliographic latitude and the active solar regions which are located generally between 7° and 20° solar latitudes. There is, however, no satisfactory explanation for the existence of the large annual component. The linear distance between the sun and the earth varies by about 1·5 per cent on either side of the mean distance and at the perihelion which occurs a few days after 1 January, the earth receives about 6·5 per cent more radiation than that at the aphelion. The corresponding increase in electron density, as computed from the average R_0 and R_1 for the 19 pairs as well as the Washington and Watheroo values is of the order of about 41 per cent which is far greater than could be expected to result from the shorter sun-earth distance. The closeness of the date on which the annual component is maximum to perihelion does, however, suggest a partial solar control of the annual component.

REFERENCES

Berkner, L. V. and Wells, H. W.	1938	*Terr. Mag.*, 43, p. 15.
Eckersley, T. L.	1940	*Ibid.*, 45, p. 25.
Mambo, M.	1957	*J. Radio Res. Lab.*, Japan, 4, 15, p. 59.
Seaton, S. L. and Berkner, L. V.	1939	*Terr. Mag.*, 44, p. 313.

M/J99DGOb—330—26-2-59—GIPS