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VARIATION OF THE F2-LAYER IONIZATION WITH SOLAR ACTIVITY AT KODAIKANAL ON MAGNETICALLY DISTURBED AND QUIET DAYS.

BY
V. R. VENUGOPAL

ABSTRACT

A study of the noon F2 layer critical frequencies at Kodaikanal has been made with a view to find a satisfactory relationship between these and different indices of solar activity, viz., sunspot numbers, areas of sunspots and areas of calcium flocculi. Following Appleton and Piggott a linear relationship has been tried out. The available data of Kodaikanal extending over a period of about half a sunspot cycle lead to the conclusion that there is a close agreement between the observed and computed values of the critical frequencies. The values of the constants involved have been computed for every month for magnetically quiet and disturbed periods separately and have been compared with similar values for Slough obtained by Appleton and Piggott.

1. *Introduction*

For accurate forecasting of ionospheric propagation conditions a thorough understanding of the characteristics of the ionospheric layers, especially of the F2 layer, is very essential. Studies made so far extending over a long period have shown that there is an increase in the ionization throughout the ionosphere with increase in solar activity and that the relative change of ionospheric critical frequency with sunspot number depends on the layer, geographical location, time of day and season. It is also known that the variation of F2 layer critical frequencies with solar activity is greater than that of other ionospheric layers and that F2 layer critical frequencies near mid-day generally vary more with solar activity than those for the other times of the day (Phillips, 1947).

Unlike the E layer and the F1 layer the F2 layer is complex in nature and it does not afford possibilities for establishing theoretically the relation between critical frequency or any other ionospheric parameter and solar activity. Allen (1946) assumes a linear relationship between the F2 ultraviolet flux SF2 and relative sunspot number R by an equation of the form $SF2=(1+bR)$. Again, Appleton and Piggott (1955) have given for Slough an empirical linear relation between the F2 critical frequency and the sunspot number R in the form $foF2=a\,(1+bR)$. Considering the greater sensitivity of the F2 layer to changes in solar activity, Phillips (1947) and Minnis (1955) suggest the determination of an 'ionospheric sunspot number' based on the values of F2 layer critical frequencies for hours near local noon as a measure of solar activity.

2. *Trend of critical frequencies as a function of solar activity*

The critical frequencies of the F2 layer at local noon (taken as the average of three values centred around local noon) at Kodaikanal (latitude: 10°14′N, longitude: 77°28′E, geomagnetic latitude: 0°.6N.) for each of the five international magnetically quiet and disturbed days for each month during the period July, 1952 to June, 1957 were obtained from the vertical sounding ionograms of the Kodaikanal Observatory. The international magnetically quiet and disturbed days were taken from the quarterly report published by the C & K Centre of the International Association of Geomagnetism and Aeronomy. The relative sunspot numbers and the areas of sunspots for the days considered were taken from the "Quarterly bulletin on Solar Activity" published by the International Astronomical Union and the United States Naval Observatory Circulars respectively. The areas of calcium flocculi were obtained from the calcium disc spectroheliograms of the Kodaikanal Observatory.

The procedure adopted by Appleton and Piggott (1955) was followed in this investigation. At first, the average critical frequencies at local noon for the five international quiet and disturbed days were considered separately for each month year by year for the period July, 1952 to June, 1957. The method of least squares was applied for establishing the relation between critical frequencies and the relative sunspot numbers. Though the linear relation $foF2=a(1+bR)$ was found to be generally satisfactory the values of 'ab' i.e., the rate of change of critical frequency with sunspot number for some months worked out to be negative. So, instead of considering the values for the five days of each month year by year, the average critical frequencies at local noon for the five international quiet and the five international disturbed days, separately of the same month of all the years (1952 to 1957), were considered and by the method of least squares the linear relation $foF2=a(1+bx)$, where x stands for the particular index of solar activity considered; i.e. sunspot numbers or sunspot area or area of calcium flocculi, was found to be an excellent fit in all the three cases as shown by the Chi-square test, the Chi square probability, P_{χ}, for goodness of fit in all cases being 0·99. The values of 'ab' in all cases were positive.

The constants of the equation $f_oF2 = a(1+bx)$ and the value of Chi-square, χ^2, were evaluated using the following formulae:—

$$a = \frac{\Sigma X^2 \Sigma f_o - \Sigma X\, \Sigma X f_o}{n\Sigma X^2 - (\Sigma X)^2}$$

$$ab = \frac{n\Sigma X f_o - \Sigma X \Sigma f_o}{n\Sigma X^2 - (\Sigma X)^2}$$

$$\chi^2 = \sum \frac{(f_o - f_c)^2}{f_c}$$

where n is the number of pairs taken, fo the observed value of critical frequency, fc the calculated value of critical frequency and x the index of solar activity considered.

3. The values of 'a', 'b' and 'ab' obtained for all the months of the year with the three indices separately for both quiet days and disturbed days are given in table 1 (given in separate sheet).

4. *Discussion*

An examination of the critical frequencies reveals that both in winter and in summer the values of foF2 for magnetically disturbed days are greater than those for the corresponding quiet days as can be seen from figs. 1 a & b. This appears to be a characteristic feature of a low-latitude station.

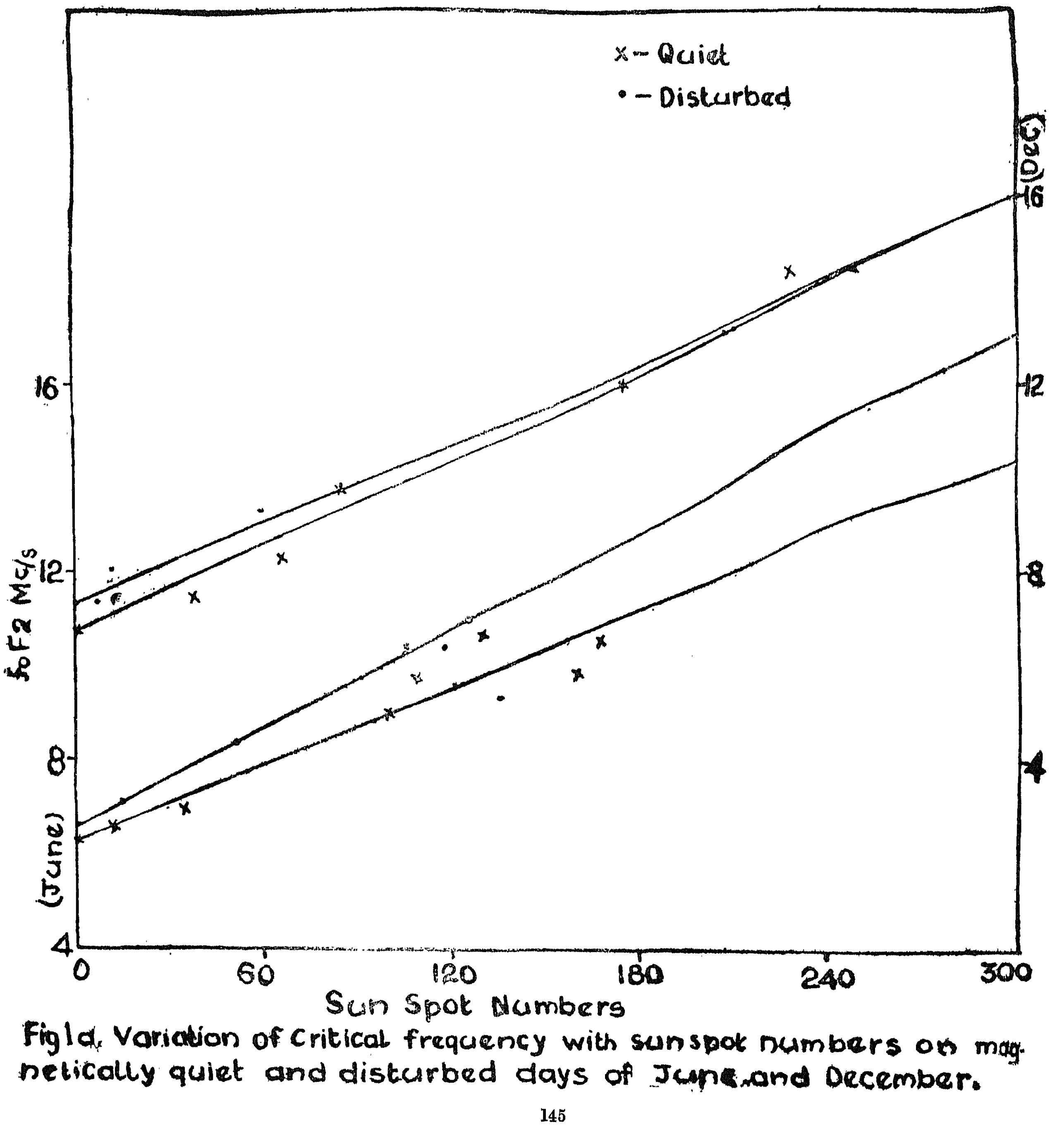

Fig 1a. Variation of Critical frequency with sunspot numbers on magnetically quiet and disturbed days of June and December.

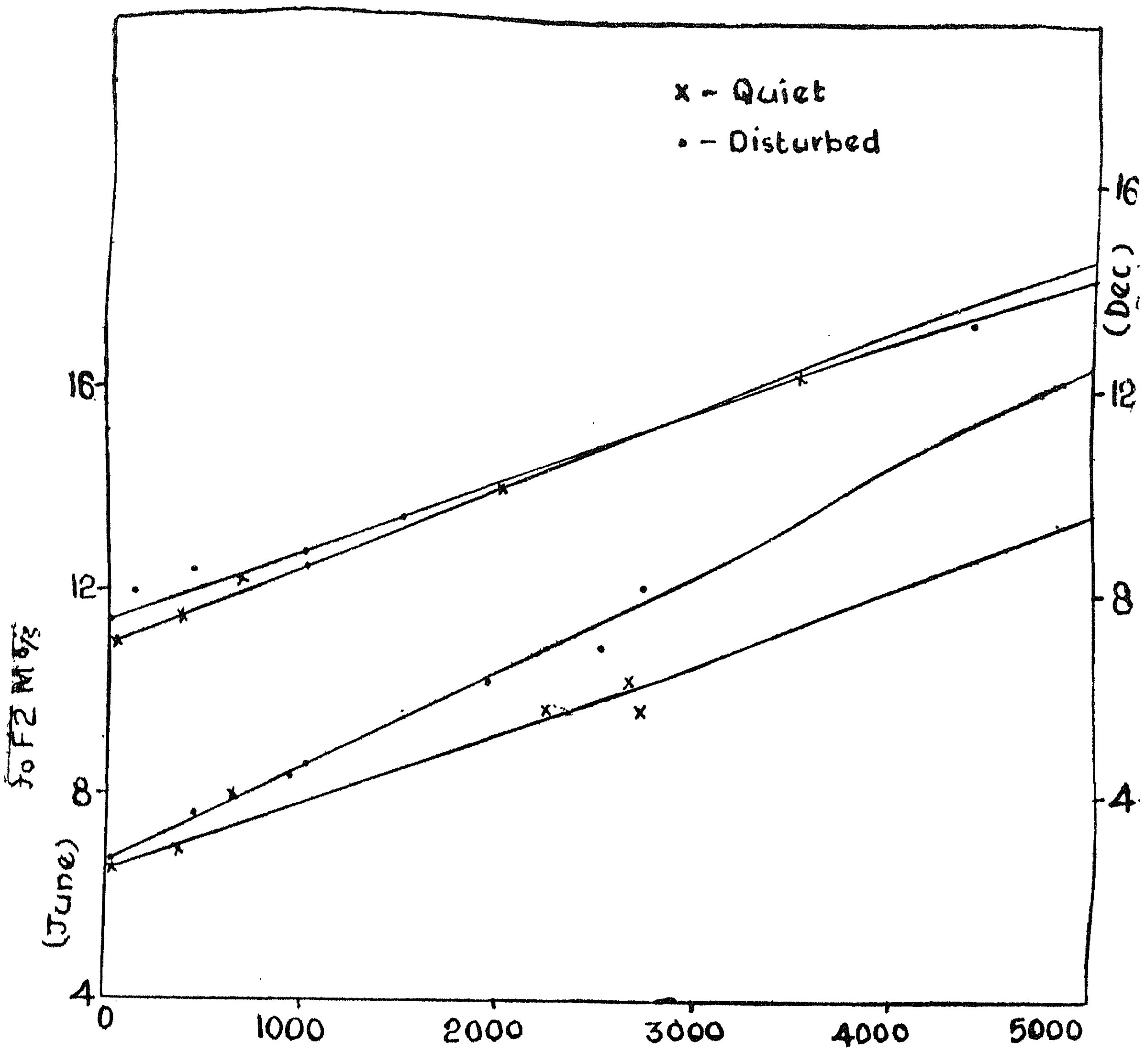

Fig.1.b. Variation of critical frequency with sun spot areas on magnetically quiet and disturbed days of June and December

For Slough, a medium high-latitude station, Appleton and Piggott (1955) have shown that in summer the values of foF2 for the magnetically disturbed days are, almost without exception, less than those for the corresponding quiet days and that for the winter months there is a tendency for the disturbed days to have slightly greater critical frequencies than the quiet days.

When the seasonal variation of the constants 'a', 'b' and 'ab' is considered for Kodaikanal and Slough substantial differences are found. Whereas for Slough it has been shown by Appleton and Piggott (1955) that the values of 'a' i.e. the magnitudes of foF2 for zero sunspot number, are practically independent of season for both disturbed and quiet days, they seem to vary with season for both disturbed and quiet days at Kodaikanal. The values of 'a' obtained separately with the three indices (sunspot numbers, areas of sunspots and areas of calcium flocculi taken in millionths of the Sun's visible disc) show seasonal variation. The mean values of 'a' are given in table 2.

TABLE 2

Mean Values of 'a' Mc/s

		With sunspot number	With sunspot areas	With calcium flocculi areas
Winter	Q	7·10	7·40	7·21
	D	7·76	7·91	7·74
Summer	Q	6·33	6·59	6·71
	D	6·89	6·95	7·10
Equinox	Q	7·30	7·25	7·37
	D	7·89	7·98	8·27

The values of 'a' for disturbed days are greater than those for quiet days for all the months at Kodaikanal. The mean values of D(a) and Q(a) for the year are given below:—

TABLE 3

Mean value of 'a' for the year	With sunspot numbers	With areas of sunspots	With areas of calcium flocculi
Quiet	6·91	7·08	7·09
Disturbed	7·51	7·61	7·70

This is also in entire disagreement with the result obtained for Slough where the value of 'a' for disturbed days D(a) is always less than that for quiet days (Appleton and Piggott 1955).

The values of Q(b) and D(b) and Q(ab) and D(ab) also are subject to seasonal variation. The effects are more clearly seen from Q(ab) and D(ab) i.e. $\frac{d(foF2)}{dX}$. In summer Q(b) and Q(ab) are considerably greater than D(b) and D(ab) but in winter the values of Q(b) and D(b) and Q(ab) and D(ab) may be taken to be almost equal even though the quiet-day values tend to be slightly greater than the disturbed day values. The values obtained using calcium flocculi areas and sunspot numbers show this aspect very clearly. For Slough in summer months D(ab) is considerably less than Q(ab) and in the winter months D(ab) tends to be slightly greater than Q(ab). During the equinoctial months the values of D(b) and D(ab) are generally greater than those of Q(b) and Q(ab) at Kodaikanal. The mean values are given in Table 3.

TABLE 3

Mean values of 'b' and 'ab'

		With sunspot numbers		With sunspot areas		With areas of calcium flocculi	
		$b \times 10^3$	$ab \times 10^2$	$b \times 10^5$	$ab \times 10^4$	$b \times 10^5$	$ab \times 10^5$
Winter	Q	3·92	2·72	16·96	12·138	2·41	16·88
	D	3·50	2·71	15·02	11·701	2·11	16·34
Summer	Q	4·34	2·75	19·62	12·930	2·32	15·51
	D	3·47	2·37	18·41	12·684	1·84	12·86
Equinox	Q	3·10	2·28	16·98	12·315	1·58	11·59
	D	3·27	2·57	21·90	17·288	1·51	12·30

It, therefore, appears that Kodaikanal has a variation of F2 layer ionization with solar activity for both magnetically disturbed and quiet days which is considerably influenced by seasonal changes.

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TABLE 1

Values of 'a', 'b' and 'ab' using the five magnetically quiet and five magnetically disturbed days each month July 1952 to June 1957

$$foF2=a(1+bx)$$

		'a' Mc/s.			b			ab Mc/s.		
		With sunspot numbers	With sunspot areas	With calcium flocculi areas	With sunspot numbers $\times 10^3$	With sunspot areas $\times 10^5$	With calcium flocculi areas $\times 10^5$	With sunspot numbers $\times 10^2$	With sunspot areas $\times 10^4$	With calcium flocculi areas $\times 10^5$
January ..	Quiet	6·59	7·10	6·68	4·07	11·41	2·36	2·68	8·137	15·79
	Disturbed	7·64	7·98	7·43	3·21	10·72	2·13	2·45	8·556	15·82
February ..	Quiet	6·75	6·89	6·57	4·98	29·14	3·83	3·36	20·079	25·16
	Disturbed	7·53	7·51	7·83	3·73	20·78	1·90	2·81	15·606	14·87
March ..	Quiet	6·99	7·03	7·10	3·75	18·94	2·12	2·62	13·313	15·03
	Disturbed	7·38	7·41	7·49	3·75	25·79	1·94	2·77	19·112	14·56
April ..	Quiet	7·54	7·01	7·21	2·69	15·47	1·73	2·03	10·846	125·0
	Disturbed	8·26	8·02	8·68	3·15	28·35	1·60	2·60	22·740	13·92
May ..	Quiet	6·65	6·77	7·43	4·18	20·90	1·90	2·78	14·152	14·08
	Disturbed	7·26	7·14	7·47	2·60	15·75	1·55	1·89	11·246	11·55
June ..	Quiet	6·31	6·57	6·53	4·40	22·93	3·73	2·78	15·063	24·37
	Disturbed	6·63	6·67	6·75	5·19	29·05	3·40	3·44	19·379	22·94
July ..	Quiet	6·10	6·37	6·28	4·77	19·13	1·41	2·91	12·188	8·86
	Disturbed	6·84	6·88	7·05	2·95	17·64	0·90	2·02	12·133	6·33
August ..	Quiet	6·27	6·65	6·58	4·02	15·50	2·24	2·52	10·307	14·72
	Disturbed	6·82	7·12	7·11	3·12	11·20	1·49	2·13	7·977	10·60
September ..	Quiet	7·13	7·41	7·38	2·57	13·23	1·05	1·89	9·800	7·75
	Disturbed	7·46	7·71	7·70	3·28	19·29	1·58	2·45	14·872	12·18
October ..	Quiet	7·55	7·54	7·80	3·40	20·29	1·42	2·57	15·299	11·08
	Disturbed	8·47	8·76	9·22	2·91	14·18	0·93	2·47	12·426	8·54
November ..	Quiet	8·25	8·52	8·19	2·13	6·94	1·43	1·76	5·917	11.71
	Disturbed	8·55	8·70	8·26	3·19	11·00	2·36	2·73	9·572	19·46
December ..	Quiet	6·80	7·08	7·38	4·53	20·36	2·01	3·08	14·418	14·87
	Disturbed	7·31	7·43	7·42	3·87	17·59	2·05	2·83	13·070	15·19

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