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The relationship of Ca-plage areas and other solar activity indices with ionospheric characteristics in *E* and *F* layers

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ABSTRACT. For the period 1938 through 1954, the monthly mean values of the two indices given by Minnis and Bazzard (1959), *viz.*, I_E and I_{F2} of the ionospheric variations through a solar cycle have been compared with solar activity indices of sunspot, faculae and calcium plage areas and λ 10·7 cm solar noise flux. It is found that while ionospheric *E* layer variations are delayed with respect to those of the above mentioned four indices of solar activity by +0·5, —0·45, 0·0 and +0·2 month respectively, the *F* layer variations are delayed by +0·8, +0·1 +0·3 and +0·5 month with respect to these solar indices. The relationships between the ionospheric and solar indices are discussed in the paper.

1. Introduction

It is well known that the X-ray and the ultra-violet flux from the sun maintaining the different ionospheric layers are composed of two components, *viz.*, the quiet sun component and the variable part associated with the solar centres of activity. All the observed aspects of solar activity namely the sunspots, faculae, plages, coronal emission and the solar radio flux, though develop at about the same time, differ in size and longevity. The solar activity indices defined either on the basis of these aspects or determined directly from the ionospheric parameters have, therefore, correspondingly a similar trend. The ionospheric variations, however, show a definite time-lag in their pattern of variations. Allen (1946, 1948) compared the relative critical frequencies Rf°*E*, Rf°*F*1 and Rf°*F*2 of the ionospheric layers *E*, *F*1, and *F*2 respectively with the solar activity indices of Zurich sunspot number, facular area and character figures for the Ca-K and H-α spectroheliograms. His results show that the facular area falls closest in phase to the ionospheric variations.

Since then the data on solar noise flux at λ 10.7 cm have become available and Kundu and Dennisse (1958) have shown that less scatter is obtained when ionospheric indices are plotted against the corresponding λ 10.7 cm flux values than against the sunspot number or sunspot area. As the solar X-ray photographs bear a very close resemblance to the corresponding Ca-Spectroheliograms (Friedmann 1962) it is very likely that the solar activity index based on the degree of Ca-plage activity might prove to be a suitable solar index for use in ionospheric studies. Recently the Kodaikanal K_{232} spectro-heliograms have been used for measuring the areas of Ca-plages in a systematic way for the period 1905 to 1954 (Kuriyan 1965).

2. Data

Calcium plage areas measured from Kodaikanal spectroheliograms have been utilised here along with other published solar activity indices. For a comparative study the Mount Wilson character figures for the Ca and H-α spectroheliograms are plotted against the corresponding Ca-plage areas for the epoch 1938 to 1945 (Fig. 2). The Mt. Wilson data have been extracted from IAU Bulletins; and for the period when they are not available, the Kodaikanal character figures, also published in IAU Bulletins, are used after scaling down to Mt. Wilson scale. Righini and Godoli (1950) compared their data on spectroheliogram character figures against Ca-plage areas from the same set of Arcetri spectroheliograms. Fig. 1 in this paper shows less scatter compared to their findings and the relationship is non-linear as is evident from the free hand curve.

In order to study the relationship between the time variations of different solar activity indices the monthly and 12-monthly running mean values of the indices for the epoch 1938 to 1954 are plotted (Fig. 1). Since the ionosphere

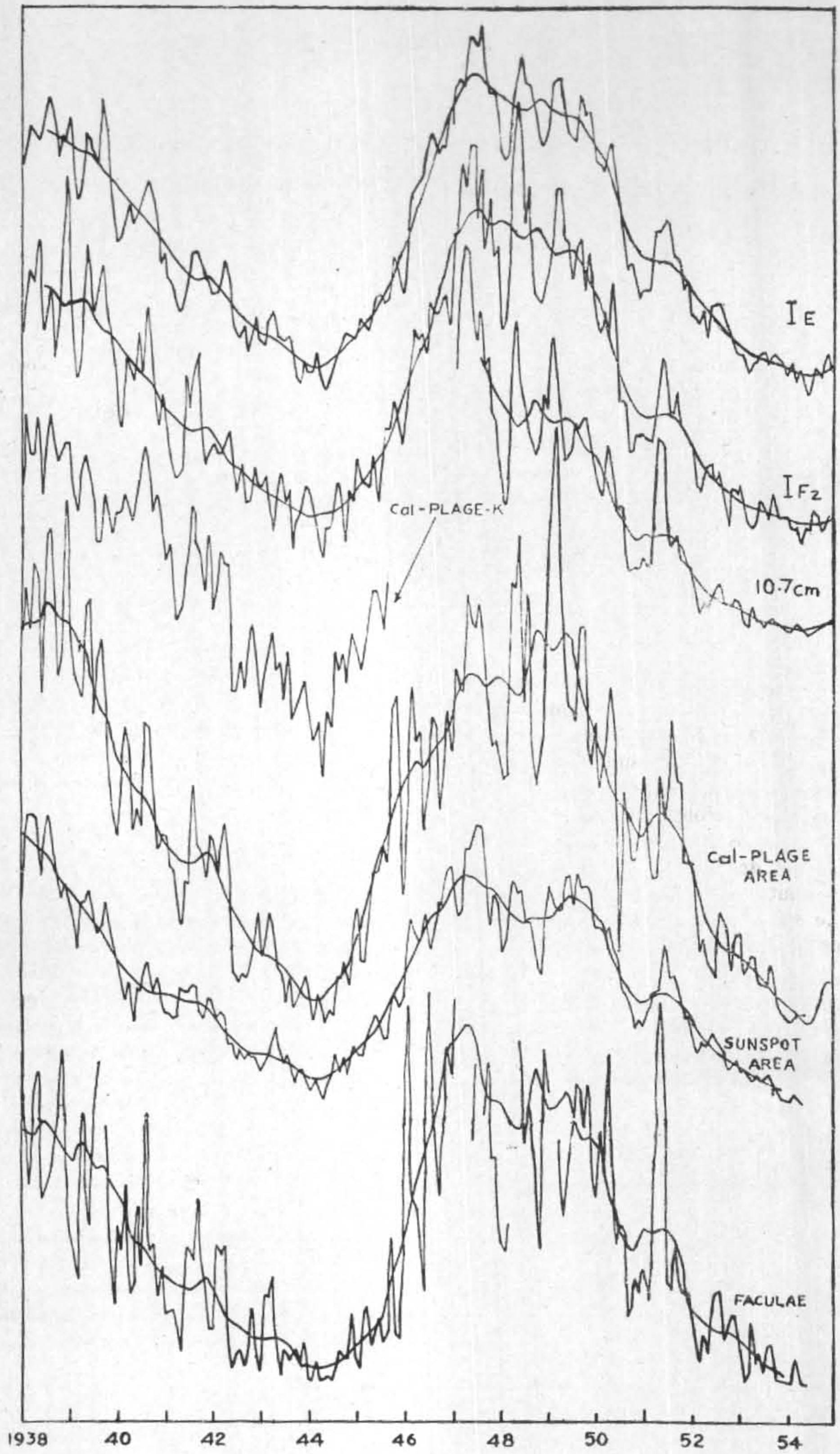

Fig. 1

Time variations of the monthly mean and the 12-monthly running mean values of the Minnis-Bazzard indices I_E, I_{F2}, C-aspectroheliogram character figure and λ 10·7 flux, projected areas of Ca-plage, sunspot and faculae

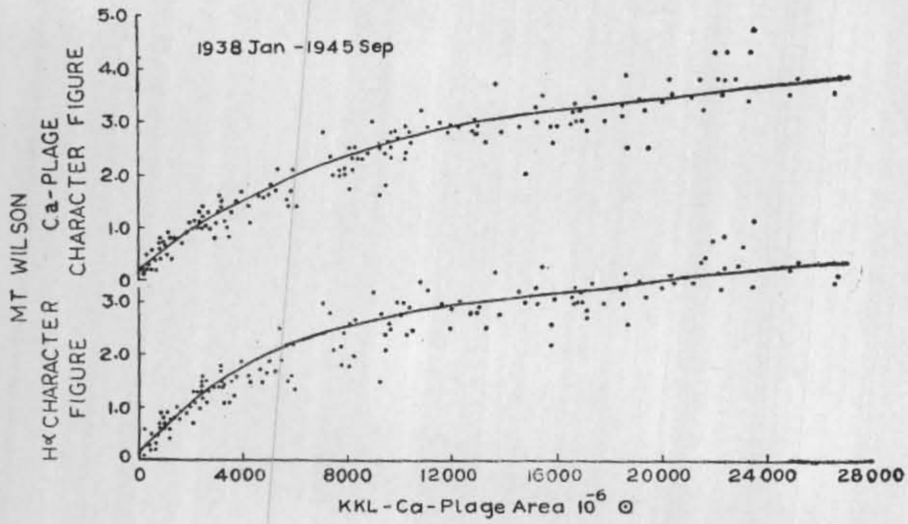

Fig. 2

Monthly mean values of the Mt. Wilson H-α and Ca-K spectroheliogram character figures plotted against the corresponding Ca-plage areas

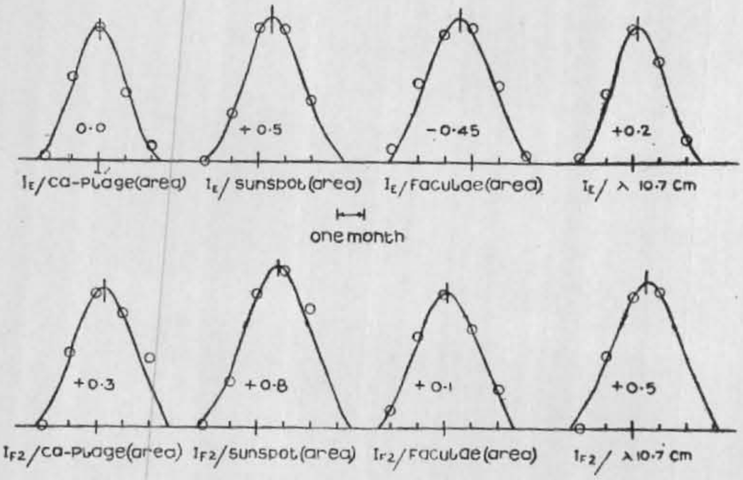

Fig. 3

Phase lag of the two ionospheric indices with respect to the four solar activity indices

is influenced by the visible aspect of the solar disc, the areas taken for the solar activity indices are the projected areas. The data on sunspot and faculae are taken from Greenwich publication (1955). The indices for I_E and I_{F_2} and λ10·7 cm solar flux values are taken from the tables given by Minnis and Bazzard (1959).

3. Results

Though, in general, the ionising radiations I_E and I_{F2} responsible for E and F layers show a similar pattern of variations as exhibited by the solar activity indices, there exists some time lag in the variations of ionospheric indices I_E and I_{F2} with respect to the peak occurrence of those solar activity indices. Fig. 3 gives the phase lags of the two ionospheric indices with respect to the four solar activity indices. These results are summarised in Table 1. For comparison, data on these phase lags of the two ionospheric indices Rf°E and Rf°F_2 with respect to Zurich sunspot number (Allen 1948) are given in the last column of Table 1.

Except in the case of faculae, the other three solar activity indices give a constant difference of +0·3 month between the I_E and I_{F2}. This, therefore, suggests the existence of a phase difference by which the F_2 layer ionisation lags behind that of the E-layer. Against this constant difference of 0·3 month the faculae alone give a difference of 0·55 month between I_E and I_{F2}. The faculae are visible only beyond the ± 60 longitude zone of the solar disc; and an additional shift in their heliographic position during the transition period when they are not visible through the central zone of the solar disc may be the cause of this difference in time lag.

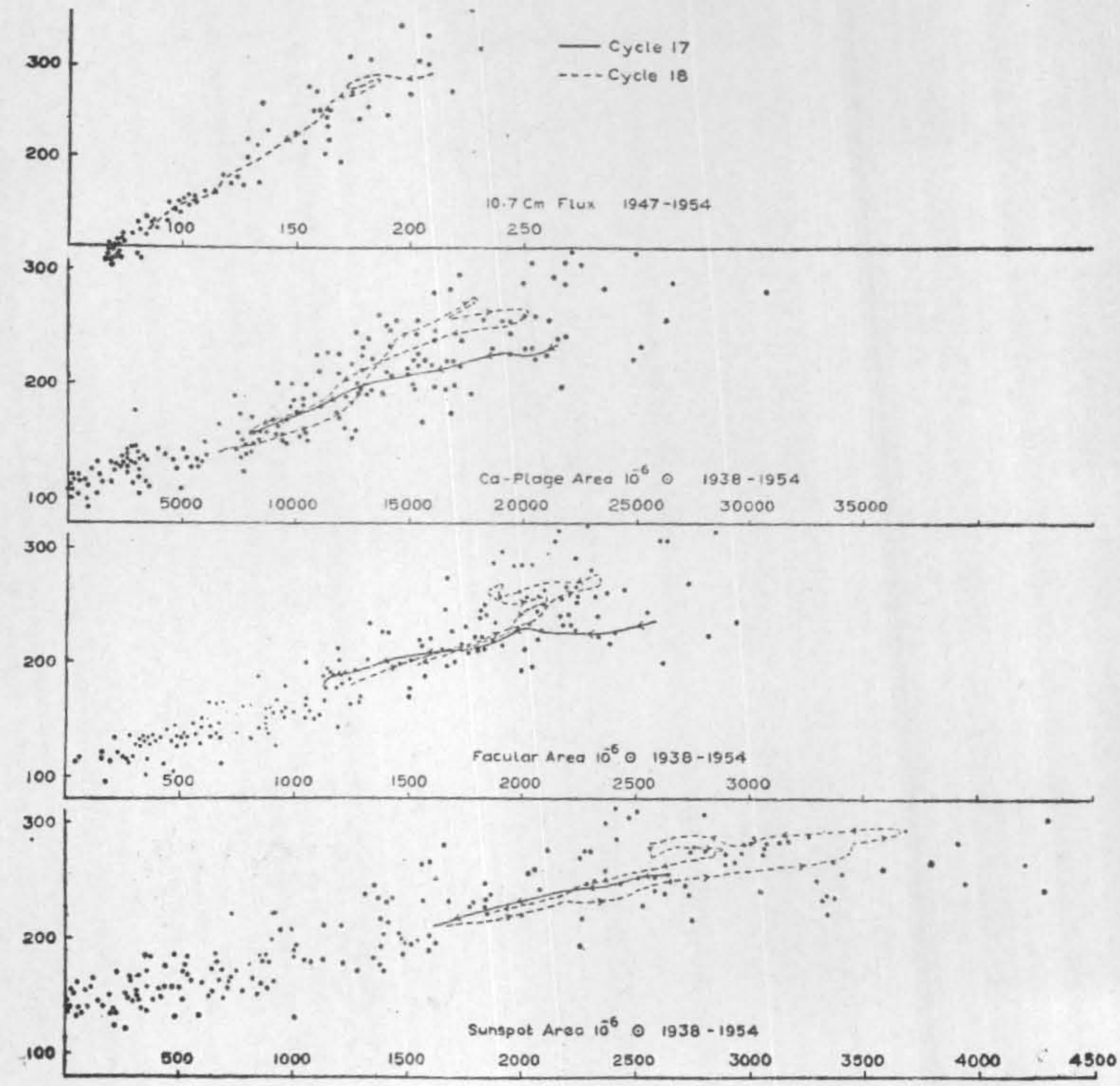

Fig. 4

Monthly mean values of the Minnis-Bazzard index I_E plotted against λ 10·7 cm flux, areas of Ca-plage, faculae and Sunspots

TABLE 1

		Sunspot area	Facular area	Ca-plage area	λ 10·7 cm flux	Zurich sunspot No.
I_E	b	397×10^{-4}	641×10^{-4}	707×10^{-5}	117×10^{-2}	
	r	0·91	0·90	0·90	0·96	
Delay		+0·5	—0·45	0·0	+0·2	
Rf°E delay						+0·43
I_{F2}	b	338×10^{-4}	600×10^{-4}	645×10^{-5}	994×10^{-3}	
	r	0·87	0·95	0·92	0·97	
Delay		+0·8	+0·1	+0·3	+0·5	
Rf°$F2$ delay						+0·68

In Fig. 4, I_E has been plotted against the four solar activity indices in the following order : λ10·7 cm flux, areas of Ca-plages, faculae and sunspots. The continuous and broken lines are obtained by joining the 12 monthly running mean values according to the time sequence for the sunspot cycle 17 and 18 respectively. A linear approximation seems to hold good for all the four cases. The correlation coefficient r and constant b of the linear regression equation $Y = a + bx$ where x is the measure of concerned solar activity index calculated by the method of least squares are given in Table 1 for both the ionospheric indices I_E and I_{F2}. It can be seen that any two indices compared amongst themselves do not decline the same way as they have increased altogether. This is supported by the recent findings of Godoli and Tagliaferri (1965).

4. Conclusions

The variation of ionospheric indices I_E and I_{F2} show closest phase relationship to calcium plage areas and facular areas respectively. But their correlation coefficient values remain lower to that of λ10·7 cm flux (Table 1). The lack of exact phase relationship between λ10·7 cm flux and ionospheric indices may arise from the existence of a considerable variation with solar activity in the quiet Sun component of the solar noise flux originating from the whole Sun (Nicolet 1963).

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