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Solar Research Memorandum No. 104

Subject: Recurrent Geomagnetic Storms and Solar Prominences

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Several investigators have suggested that the hypothetical M-regions (the solar source of corpuscular radiation which produce recurrent geomagnetic storms) are to be identified as the extended white light coronal streamers (1) (2). A limited number of observations of these white light streamers, at time of natural solar eclipse, show them to be best associated with filamentary type prominences and directed away from active sunspot regions (3) (4). The appropriate hypothesis has been advanced by Waldmeier (5) and by Kiepenheuer (6) that stationary (quiescent) prominences should be associated with geomagnetic storms.

Waldmeier (5) compared the day-by-day areas of prominence profiles, for 1930, and the character numbers of H-alpha filaments (from the IAU Quarterly Bulletins of Solar Activity), for April - December 1943, with geomagnetic indices for the same periods. He concluded that the sequences of recurrent magnetic storms during these periods were related to the stationary prominences. Assuming the corpuscular flux to be directed radially from the sun in the coronal streamers, the time required for the particles to reach the earth was about 5.5 days.

Kiepenheuer (6) measured the projected areas of the filaments in a band 14° wide in heliographic longitude at the central meridian of the solar disk. He then used the superposed epoch method to study the variation of filament areas around magnetically disturbed and quiet days for a period of low solar activity, 1922-1924, and a period of high solar activity, 1926-1928. For 81 magnetically disturbed days in 1922-1924, he found a maximum of filament areas four days earlier. The maxima of filament areas were in the range of 10% above the mean values for the earlier period. The relation between filaments and magnetic activity was lost as solar activity increased.

Trotter and Roberts (7) compared the average areas of prominences with the five most geomagnetically disturbed and the five most magnetically quiet days for each month in the periods May-November 1951, February-October 1953, and February-June 1954. Using a superposed epoch analysis, they found no significant trend of prominence areas around either the magnetically disturbed or magnetically quiet days.

Leighton and Billings (8) performed the same type of study as that by Trotter and Roberts for the same time period, but used measurements of disk filament areas rather than limb-prominence areas. They concluded that the magnetic storms could not be associated with dark filaments in the period studied.

The purpose of the present study is to examine uniformly the association of solar filaments with recurrent magnetic storms over a longer time period than has been attempted before. Also, we are interested specifically in the association of filaments with recurrent magnetic storms, rather than magnetic storms, per se. It should be noted that in some of the studies reported above, where the "most magnetically disturbed" days for each month were considered, the data sample was strongly diluted by sudden commencement, non-recurrent sequence magnetic storms. Statistical studies by Greaves and Newton (9) and Allen (1) give substantial evidence that two basic types of geomagnetic storms may be distinguished, based upon the characteristics of recurrence, association with sunspots and flares, storm intensity and abruptness of commencement. We are here investigating recurrent magnetic storms. In the general case, such storms are non-sudden commencement and not associated with sunspots or flares.

The list of recurrent magnetic storms was compiled by Dorothy Trotter (unpublished) for the period 1906-1953. We used the "Character Figures for Dark H-alpha Flocculi", published in the IAU Quarterly Bulletins of Solar Activity (from 1917-1944) as an index of solar filament areas. These character figures were assigned on a scale of 0-5, with the numbers referring to intensity and area of the dark hydrogen filaments for each day. The figure "0" was used to designate absence or extreme rarity; and "5", extreme abundance and intensity. Righini (10) systematically compared filament character figures with measured areas of dark filaments from Arcetri and Mount Wilson spectroheliograms, and concluded that "character figures appear to be a function of area alone".

For the first part of our study, we performed a superposed epoch analysis of the run of dark filament indices around the approximate maximum day of geomagnetic disturbances. (Figures 1-9) Nine well-defined sequences of geomagnetic storms occurred during the years 1918 through 1944. In some cases, such as the sequence in 1923, there is a clear-cut maximum of filament areas before the storm; in other cases, such as the sequence of 1944, there is a minimum of filament areas before the magnetic storm. But the graphs show no consistent relations between filament areas and dates of recurrent magnetic storms.

Next we considered the run of geomagnetic index figures around dates of high filament areas, using the same superposed epoch analysis technique. (Figure 10) For the years 1942-1944, we chose as zero days the days of maxima of the trends in filament indices, provided the index values were at least 150% of the monthly mean. There were 59 cases in the time period. No increase of geomagnetic activity is seen following days of large filament areas on the sun; the plots show, if anything, a slight decline.

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tc

End of Memo

References

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(3) Kiepenheuer, 1953, The Sun, page 417

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(5) Waldmeier, M., 1946, Terr. Mag. and Atmos. Elec., 51, 537

(6) Kiepenheuer, K.O., 1947, Ap.J., 105, 408

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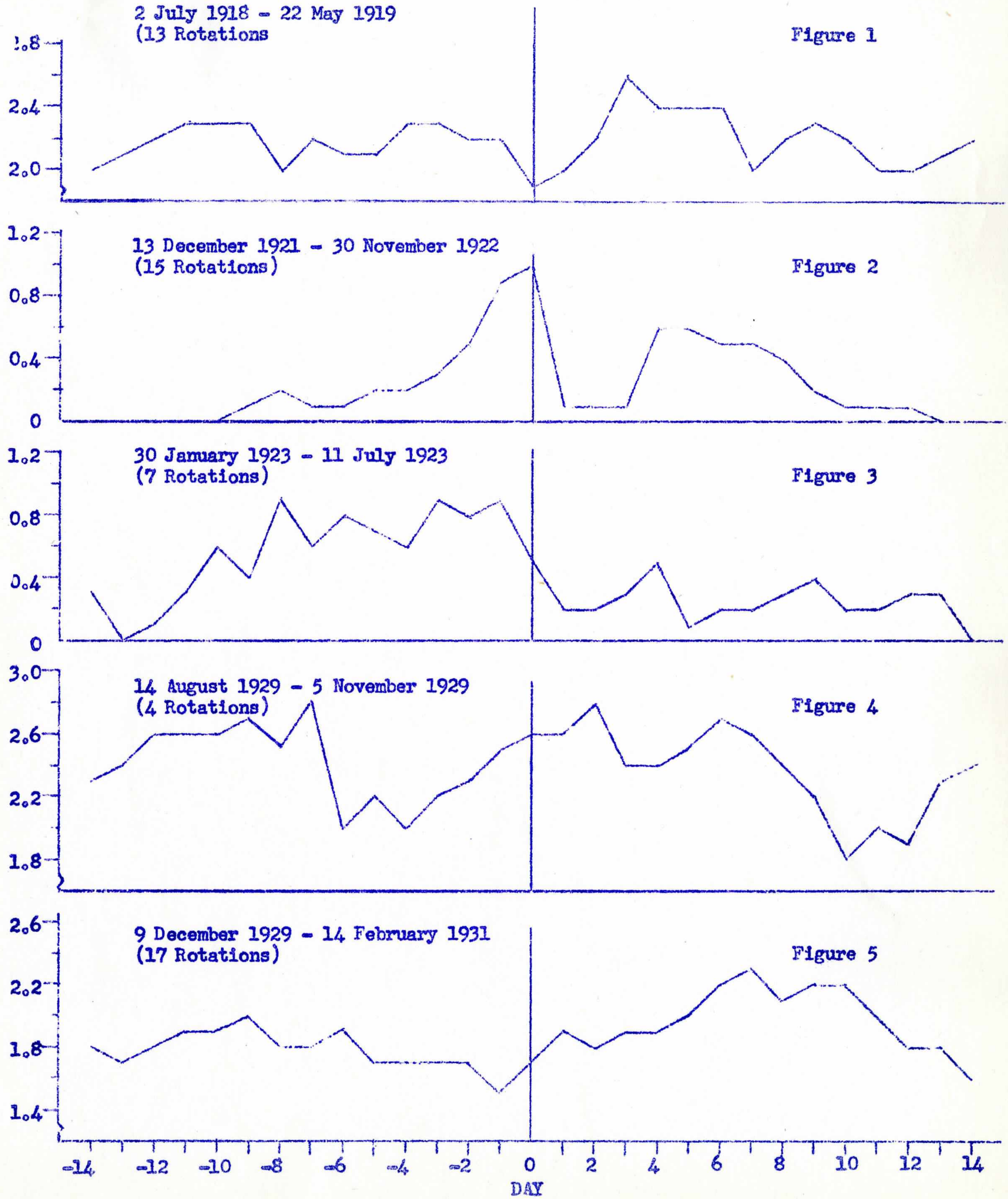
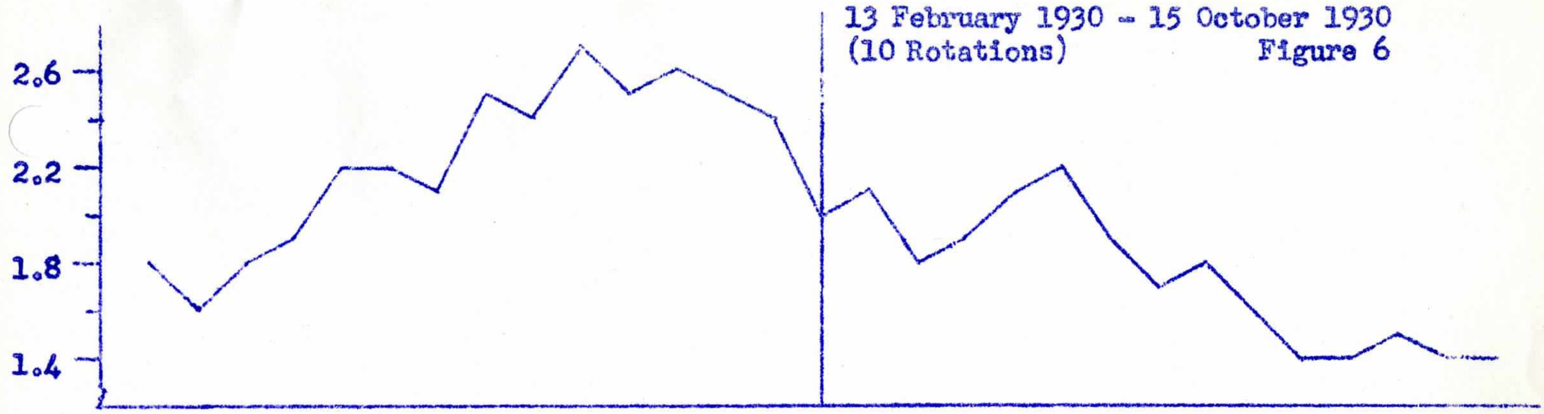
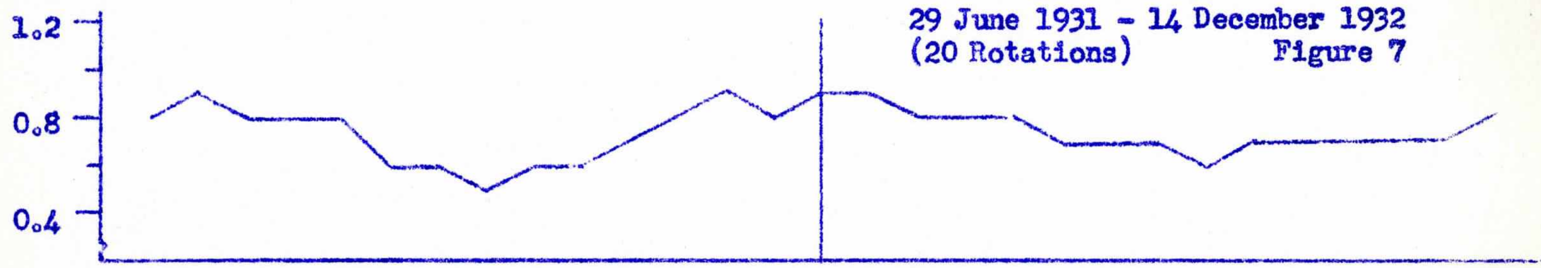
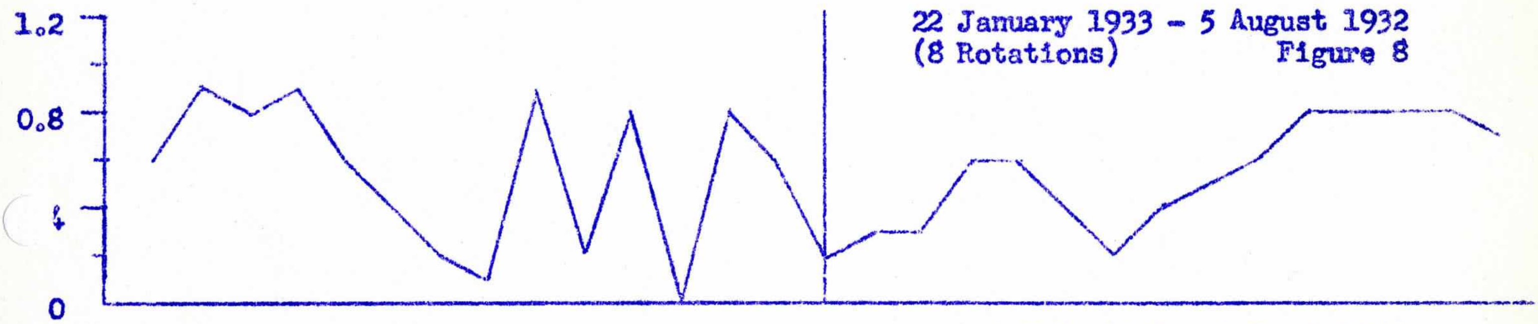
(10) Righini and Godoli, 1950, Journal Geo. Res., 55, 4

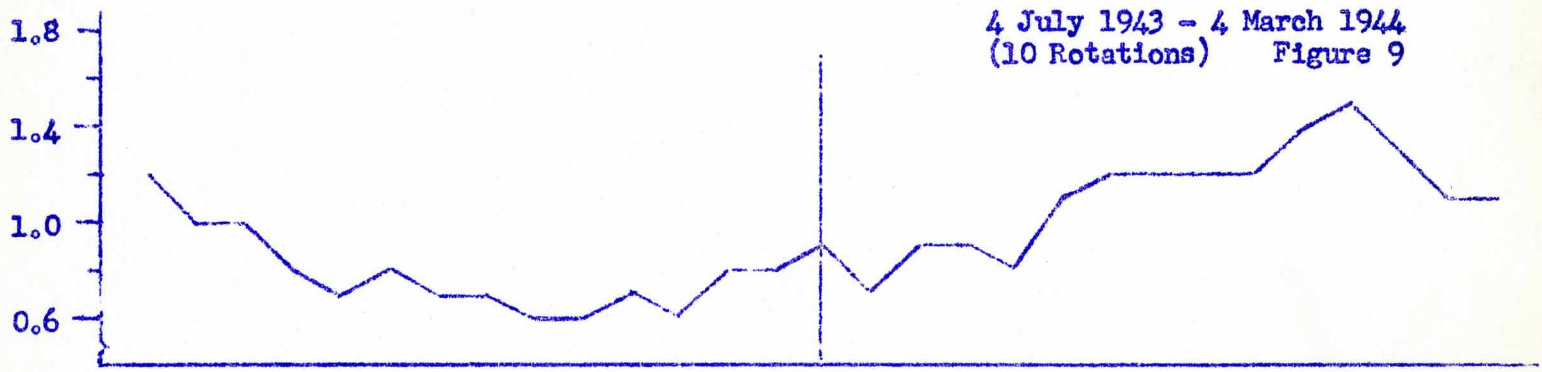
Solar Filament Areas Versus Day of Maximum Geomagnetic Disturbance,
For Sequences of Recurrent Magnetic Storms

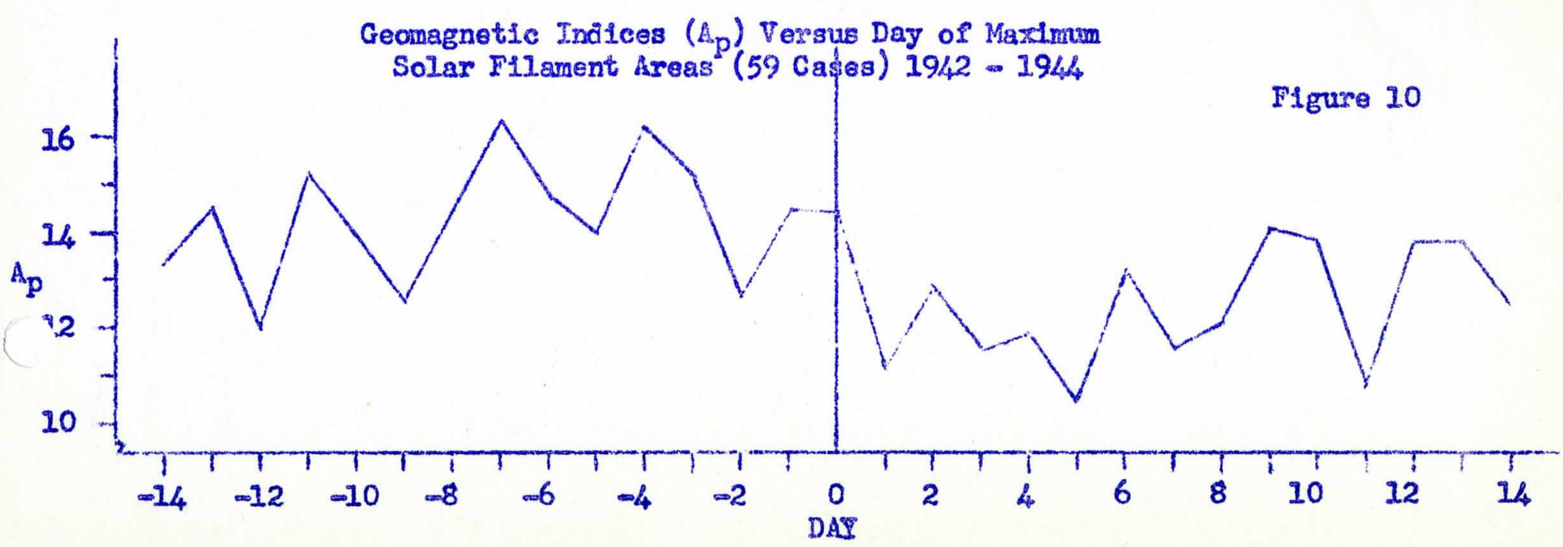



13 February 1930 - 15 October 1930
(10 Rotations)
Figure 6
2.6
2.2
1.8
1.4


29 June 1931 - 14 December 1932
(20 Rotations)
Figure 7
1.2
0.8
0.4


22 January 1933 - 5 August 1932
(8 Rotations)
Figure 8
1.2
0.8
0


4 July 1943 - 4 March 1944
(10 Rotations)
Figure 9
1.8
1.4
1.0
0.6


Geomagnetic Indices (A_p) Versus Day of Maximum
Solar Filament Areas (59 Cases) 1942 - 1944
Figure 10
16
14
A_p
10
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
DAY