550.38 : 523.74

A filter analysis of Magnetic Activity Index *Ap* for 1932-33 and 1952-53

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ABSTRACT. During 1932-33 and 1952-53 periods of predominantly recurrent magnetic activity, application of appropriate low-pass and band-pass numerical filters to time series of daily indices, *Ap*, has been made to examine the magnitude of 27-day recurrence and to isolate the recurrent activity. The number of solar centres of activity, the solar hemispheres of these centres, their probable latitudes and the approximate angles of the corpuscular streams have been inferred from the filtered time series.

1. Numerous investigations have been carried out on recurrent magnetic disturbances which occur during the declining periods of solar cycles. The solar centres (M-regions) responsible for recurrent storms were investigated several decades back by Bartels (1932) who found no association of these with visible solar activity. Allen (1944) showed that active regions responsible for recurrent disturbances, had a tendency to avoid sunspot areas. The association of other solar features with recurrent storms have been attempted from time to time. The M-regions have been shown to be long-lived, as much as 2 to 3 years (Bhargava and Naqvi 1954). Bell and Glazer (1957) showed that active regions on the same side of the solar equator as the earth have more influence on the geomagnetic activity than the regions in the other solar hemisphere. Meyer (1966) has, however, suggested that the maxima of the 6-monthly wave in the recurrent activity occur at equinoxes rather than at the times of maximum inclination of sun's axis towards the earth. Attempts have been made (Naqvi and Bhargava 1954) to determine the number of M-regions and solar hemispheres of their location. The heliographic latitudes for the regions responsible for recurrent activity during 1950-53 were indicated by them as higher than 7·2°. Tandon (1956) deduced the number of active regions and their hemispheres during each of the 4-year periods preceding solar minima from 1920 to 1954.

2. Bartel's musical diagrams of planetary *K* index, available from 1932, provide an excellent indication of the magnitude of recurrent geomagnetic activity during any period of solar cycle. A perusal of the diagrams for declining periods of solar cycles shows the magnitude of the recurrence, the semi-annual and annual effect as well as the extent of activity unrelated to long-lived active regions. In most of the years during declining solar activity considerable extraneous activity unrelated to long-lived M-regions is found to exist. During some periods, however, most of the activity is of recurrent type. These periods, when the recurrent activity predominated, included the years 1932-33 and 1952-53. Reference to Bartel's diagrams shows that apart from the 27-day periodicity, a tendency for maxima of activity to occur at intervals of 8 to 9 days existed during these years. This feature can be ascribed to several active regions existing on the sun at the same time. These characteristics of the activity have been utilized, in the present communication, to infer, by the application of suitable statistical filters to series of daily values, the number and position on the solar disc of the responsible solar centres of activity.

3. In the studies of geophysical problems, increasing use has recently been made of smoothing and filtering functions. By proper use of numerical filters very useful effects can be realized by the removal of unwanted spectral components. The time series composed of *Ap*, the daily equivalent planetary amplitude, representing recurrent geomagnetic activity during the periods 1932-33 and 1952-53, were used for the filter analysis. In order to eliminate the higher frequencies due to extraneous activity and to isolate the series which constituted only recurrent activity, the series were filtered with a band-pass filter of peak response at a period of 8 days and fairly high response for periods between 6 and 12 days. A symmetric 13 point filter (No. 114), designed by Craddock (1957) having these response characteristics (Fig. 1) was used. Each of the series X_n formed by daily *Ap* for 731 days beginning with 1 January 1932 and 1 January 1952 was filtered using this band-pass

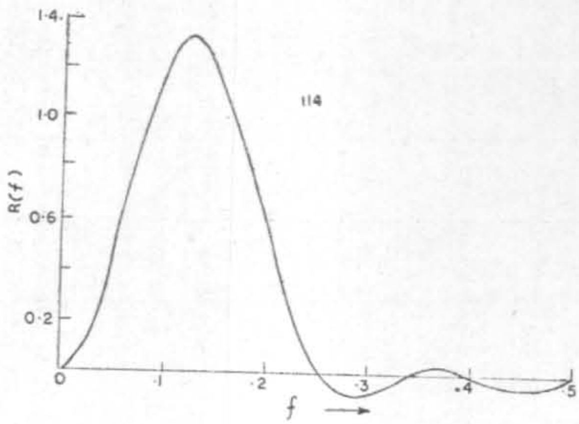

Fig. 1. Frequency response, R(f), of Craddock's band-pass filter No. 114
Frequency, f, is in cycles per data interval

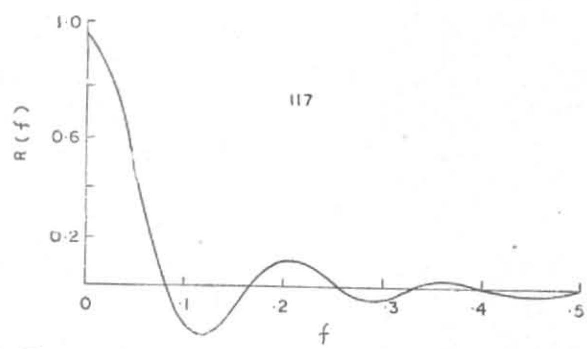

Fig. 2. Frequency response, R(f), of Craddock's low-pass filter No. 117
Frequency, f, is in cycles per data interval

filter. The filtered series Y_n was obtained from—

$$Y_n = \sum_{j=0}^{6} \tfrac{1}{2} W_j \, (X_{n-j} + X_{n+j})$$

where W_j are the weights, W_0 being the central weight and W_1 to W_6 twice the weights of the symmetric filter.

4. In order to examine the nature of longer periodicities, each of the two series were also smoothed using a low-pass filter to discriminate against periods shorter than 15 days. The response of this filter (Craddock 1957) is reproduced in Fig. 2. The computations were carried out on CDC 3600-160 A computer.

5. The smoothed time series for 1932-33 and 1952-53 shown in Figs. 3(a) and 4(a) respectively, demonstrate the magnitude of the 27-day recurrence during the 2-year periods. The tendency for the 27-day periodicity to be strong during the months around the equinoxes is obvious. During 1932-33 strong recurrence is noticed from the end of February to middle of April 1932, from middle of August to early October 1932, from middle of January to early April 1933 and from early September to middle of October 1933. During 1952-53 very strong 27-day recurrence is observed from the end of February to middle of May 1952, from end of August to middle of October 1952, from middle of February to early April 1953 and from middle of August to early December 1953. The expected semi-annual oscillation in Ap with maxima around the equinoctial months may be noticed in Figs. 3(a) and 4(a).

6. The principal features of magnetic activity as observed from band-pass filtered series, shown in Fig. 3(b) for 1932-33 and in Fig. 4(b) for 1952-53 are as follows.

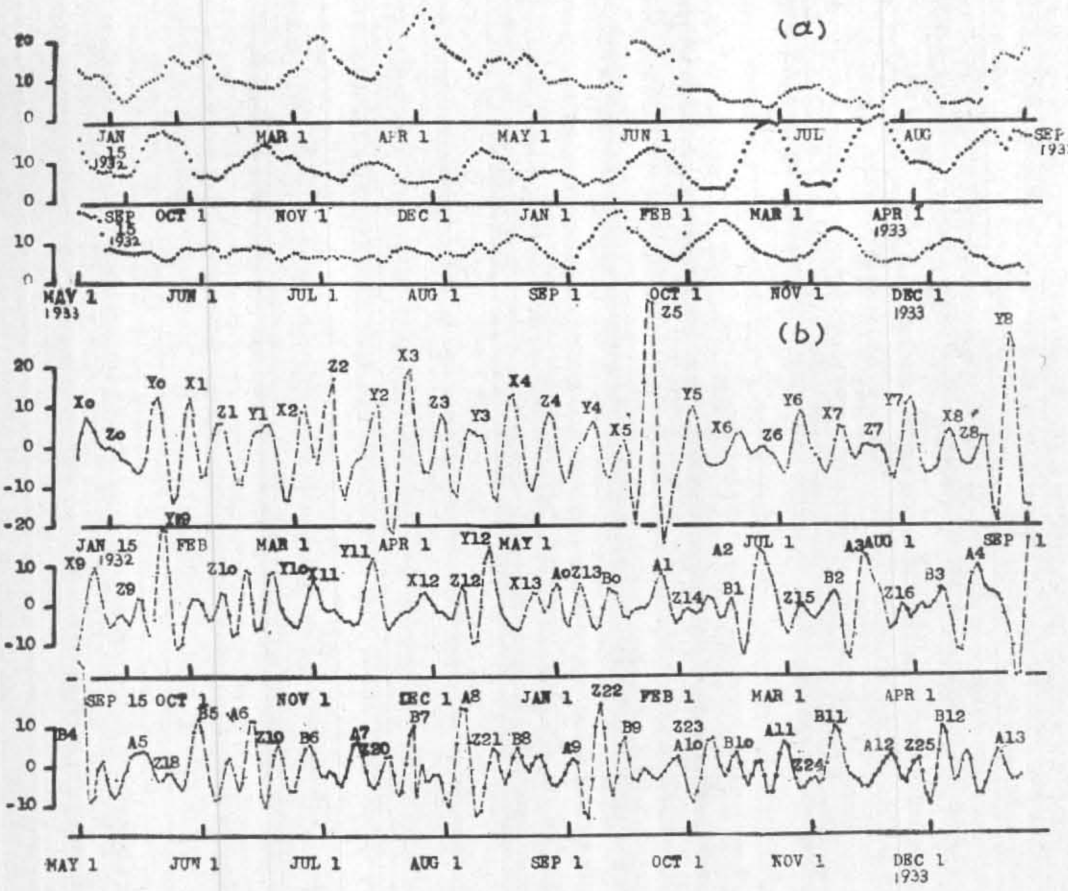

Fig. 3. (a) Long period variations and (b) shorter period variations in Ap for 1932-33

1932–33

(1) The recurrent activity during 1932-33 was composed of 3 series of disturbances during the earlier part of the period. These are maked X, Y and Z in Fig. 3 (b).

(2) By the end of 1932 the activities associated with these three centres decreased substantially.

(3) Series X and Z occurred with comparatively large oscillations around the autumnal equinox while series Y had maximum activity around the vernal equinox. Assuming axial hypothesis it may be inferred that the solar regions of activity responsible for series X and Z were located in the northern solar hemisphere, while that contributing to Y series was in the southern hemisphere.

(4) The solar longitudinal separation among the three active regions were on the average as follows: X to Y 120°, Y to Z 129° and Z to X 107°.

(5) Two new recurrent series, observed from January 1933, indicate the appearance of two new centres of activity. The first one marked A, continued till throughout the year. The second one marked B, started with small oscillations of irregular periods. Its recurrence became regular from June and it continued till the end of the year.

(6) Series A appeared with comparatively large oscillations around the autumnal equinox while series B showed a tendency for large oscillations around the vernal equinox. Again assuming the axial hypothesis it may be inferred that the active region responsible for series A was located in the northern solar hemisphere while that responsible for series B was in the southern solar hemisphere.

(7) The separation of A and B in solar longitude was about 141°.

(8) No systematic change in the period between peak activities in any of the series is observable.

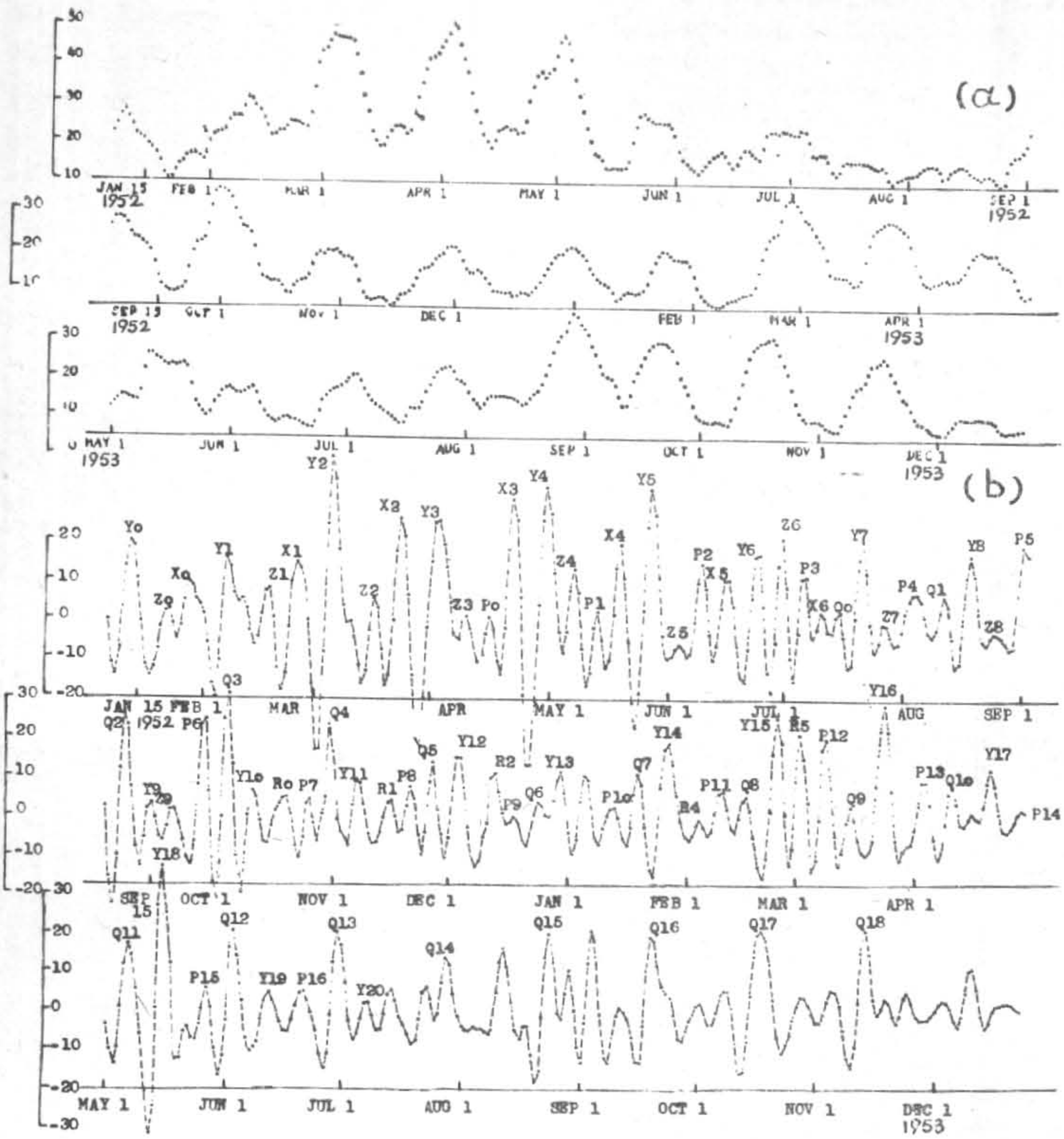

Fig. 4. (a) Long period variations and (b) shorter period variations in Ap for 1952-53

1952-53

(1) During the earlier part of the period three recurrent series, X, Y and Z are identifiable, two of which, series X and Z, were comparatively short-lived.

(2) Both the series X and Y occurred with large oscillations around the vernal equinox and, therefore, the solar active centre responsible for these series can be inferred to be in the northern solar hemisphere. Series Z with comparatively small oscillations, did not occur with larger amplitudes during any one of the equinoxes.

(3) The longitudinal separation between the series X and Y was about 121°, that between Y and Z 104° and that between Z and X 125°.

(4) Three fresh centres of activity, as shown by series P, Q and R came into existence during the later part of the period. The centre responsible for the series P appeared in May 1952 and lasted till about June 1953; that for the series Q appeared in July 1952 and continued till about the end of 1953. The third centre, responsible for R comprised of small oscillations from October 1952 and became insignificant after March 1953.

(5) Series P and Q occurred with large oscillations around the autumnal equinox, indicating that the corresponding solar active regions were located in the southern solar hemisphere.

(6) The solar active regions responsible for P and Q were separated by about 84° solar longitude.

(7) As in 1932-33 no systematic change of period in any of the series is observable.

7. From Figs. 3(b) and 4(b) the average periods between peaks of the activities associated with series X, Y, Z, A and B for 1932-33 and for X, Y, Z, P and Q for 1952-53 are shown in Table 1. Assuming the active centres (M-regions) to be situated at about the same level on the sun as sunspots and faculae their corresponding solar latitudes, deduced from the variation of solar-rotation period with latitude (Allen 1955) are shown in Table 1. It is noticed that all the active regions, responsible for the recurrence of geomagnetic activity, appeared around 34° solar latitude.

8. The periods considered in this analysis are just prior to the epochs of minimum solar activity when the sunspots are known to be located around 7°-12° solar latitude with the latitudes of 33°-34° being free of sunspot activity. The inference here that M-regions are located at about 34° solar latitude indicates that the latitudes of M-regions are far removed from those of concurrent sunspots. This is in agreement with the conclusion by Allen (1944) that M-regions tend to avoid areas of sunspots and with the suggestion of Waldmier (1950, 1962) that M-regions are very old and dead centres of activity devoid of sunspots.

TABLE 1

Average periodicities for M-regions and their location in the solar latitude during 1932-33 and 1952-53

Recurrent Series	Average period (days)	Latitude of corresponding solar M-region (degrees)	
		1932-33	
X	26·83	32·6	Average 33·1
Y	26·66	31·4	
Z	27·36	36·4	
A	26·92	33·2	
B	26·71	31·7	
		1952-53	
X	27·33	36·1	Average 34·2
Y	27·13	34·7	
Z	26·89	33·0	
P	26·94	33·4	
Q	27·03	34·0	

9. Assuming that M-regions appeared at solar latitudes 33°–34° and that the maxima of geomagnetic activity around the equinoxes arise from the variation in the earth's heliographic latitude (maximum of 7·2°N on 5 March and maximum of 7·2°S on 7 September) it is possible to estimate the angular width of the corpuscular streams from the M-regions. From the mean latitude of M-regions 33·5° deduced here, the mean sun-earth distance of $14{\cdot}935 \times 10^7$ km and the radius of the sun $0{\cdot}069 \times 10^7$ km, it is easy to show that for the occurrence of semi-annual peaks in recurrent activity the angle of the corpuscular stream in the solar longitudinal plane should not exceed 67° and should not be less than 53°. This is in fair agreement with the value of 66° calculated by Basler and Owren (1964).

10. Since no systematic change of the period between successive peaks in any of the series is noticed no indication can be had regarding progressive migration, in latitude, of M-regions. Alternately a period of 2 years, investigated here, is too small to detect possible migration, in latitude, of the active regions.

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