POLEWARD MIGRATION OF THE MAGNETIC NEUTRAL LINE AND THE REVERSAL OF THE POLAR FIELDS ON THE SUN

II: *Period 1904–1940*

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Abstract. Poleward migration of the magnetic neutral line on the Sun has been computed for the period 1904–1940 using synoptic charts based on Hα observations and the epochs of sign reversal of the solar magnetic field at latitudes 50° to 90° have been determined for this period. During the cycles 16 and 14, a threefold sign reversal took place in the northern and southern hemispheres, respectively. During all the cycles studied both the solar poles were of one polarity for a period ranging from 0.6 to 1.6 years. The poleward drift velocity of the neutral line varies from 4.2 to 8.2 m s^{-1}. The apparent relation between the velocity of the filament bands when three bands are present with the bursts of solar activity is discussed.

1. Introduction

In an earlier paper (Paper I, Makarov *et al.*, 1983), we used the poleward migration of the magnetic neutral line for deriving the polarity reversal of the magnetic field in the vicinity of the polar regions on the Sun for four cycles during 1945–1981. The close agreement of the epoch of the reversals derived from our migration trajectory diagrams with those from direct magnetograph observations in cycles 20 and 19 encouraged us to continue the investigation.

2. Data and Reduction

Kodaikanal plate vault has Hα and K_{232} spectroheliograms commencing from 1904 and so we extended our studies back in time till this year, thus covering four more cycles (1904–1940). For the period 1919–1940, we used the Meudon charts of the distribution of filaments along with the Hα and K_{232} spectroheliograms to construct the synoptic charts in the way described in detail in Paper I. For the years prior to 1919, Meudon charts do not exist. We, therefore, constructed the synoptic charts starting from blank charts and marking the active regions and then the filament and filament channels, all the information being drawn from Kodaikanal Hα and K_{232} spectroheliograms. We then derived the trajectory of the migration of the neutral line for the four cycles, following the procedure outlined in Paper I.

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3. Results: Sign Reversal of the Polar Fields

3.1. Solar Cycle 17

The migration trajectories of the neutral line are presented in Figure 1. There were two filament bands in both the hemispheres. The times of onset of their poleward drift coincided with the enhancement of activity. The mean velocity of the band drift at high latitudes was 4.5 m s^{-1}. In both the hemispheres the polarity change took place only once. However, poleward of 75° considerable fluctuations in the latitude of the neutral line are seen during 1939. Although the process of the polarity change ended almost simultaneously at both the poles by the start of 1940, it lagged behind the maximum burst of activity at the north and south hemispheres by 2.6 and 1.6 years, respectively. The results on the polarity change within the latitudes 50°–90° are given in Table I.

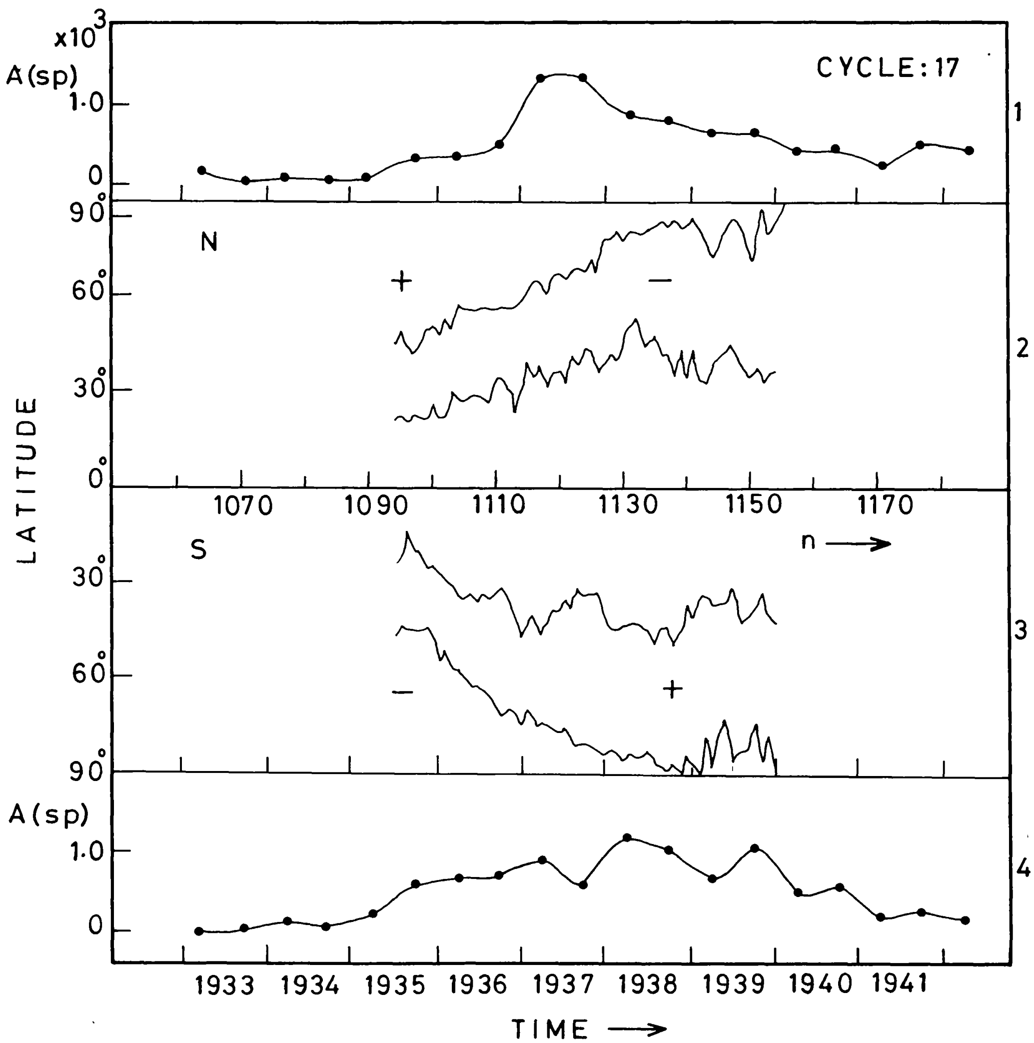

Fig. 1. The trajectory of the migration of the mean latitude of the neutral line of the large scale magnetic field for solar cycle 17. N – northern hemisphere; S – southern hemisphere; + and – stand for the polarity sign of the magnetic field in the conventional way; *n* – number of the Carrington solar rotation. Time is in years. Curves in boxes 1 and 4 are the plots of the six monthly means of the mean daily areas of sunspots *A*(sp) expressed in millionths of the visible hemisphere for this cycle for the north and south hemispheres, respectively.

3.2. Solar cycle 16

Figure 2 shows the trajectories of the drift of the mean latitude of the neutral line for the rotations 940–1031. The filament bands started poleward migration simultaneously with the enhancement of the solar activity by mid 1925. The first filament band '*A*' in the northern hemisphere migrated towards the pole with a mean velocity of 4.6 m s^{-1} and reached the pole in the year 1927.9 reversing the polarity from − to +. The second filament band '*B*' was at the latitude 50° in mid 1926 and reached the pole in 1929.3. This caused the second polarity reversal at the polar region. The third filament band '*C*' reached the pole in 1929.9, changing the polarity to positive. The bands *B* and *C* moved over to the pole with velocities of 5.5 m s^{-1} and 8.2 m s^{-1}, respectively. It is interesting to note that all the three bands showed a simultaneous equator-ward shift with a velocity of ~ 17 m s^{-1} in 1927. In the southern hemisphere, the polarity change was caused by only one filament band moving with a velocity of 4.2 m s^{-1} and the final reversal took place in 1928.5. During this cycle on two spells (1927.9–1928.5 and

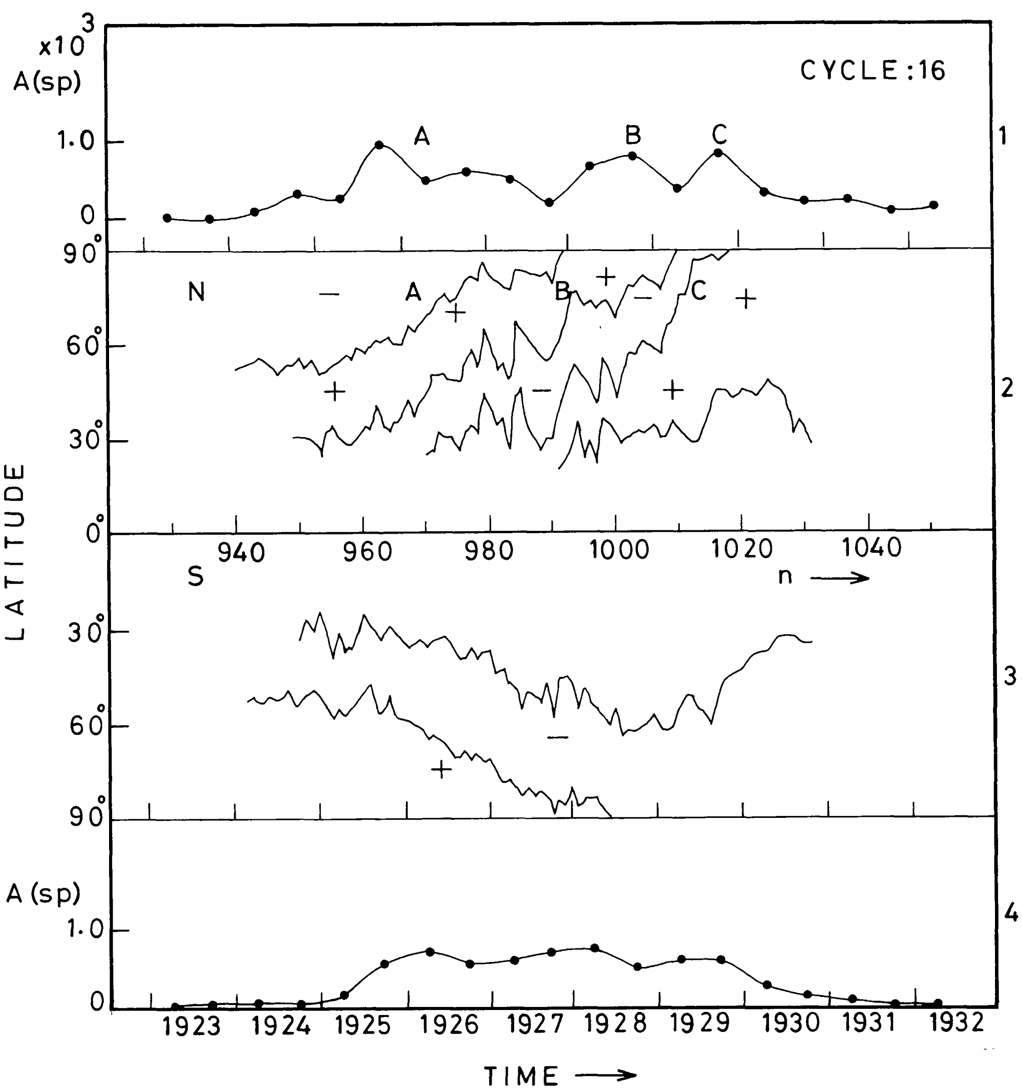

Fig. 2. Same as Figure 1 for cycle 16.

1929.3–1929.9) both the poles had the same polarity sign, positive in the former and negative in the latter spell.

3.3. Solar cycle 15

In this cycle, there were only two filament bands in both the hemispheres (Figure 3). The time of the onset of their poleward migration coincided with the enhancement of activity as in other cycles. The process of sign reversal of the polar field is very similar to that in cycle 17. The mean velocity of the filament band at high latitudes was 4.5 m s^{-1} in both the hemispheres. The polarity reversal also took place almost simultaneously in the second half of 1918 and ended 1.0 year after the solar maximum.

3.4. Solar cycle 14

In the northern hemisphere, the time of onset of the poleward migration of the filament band coincided with the peak of the solar maximum (Figure 4 – see curve in box 1). The

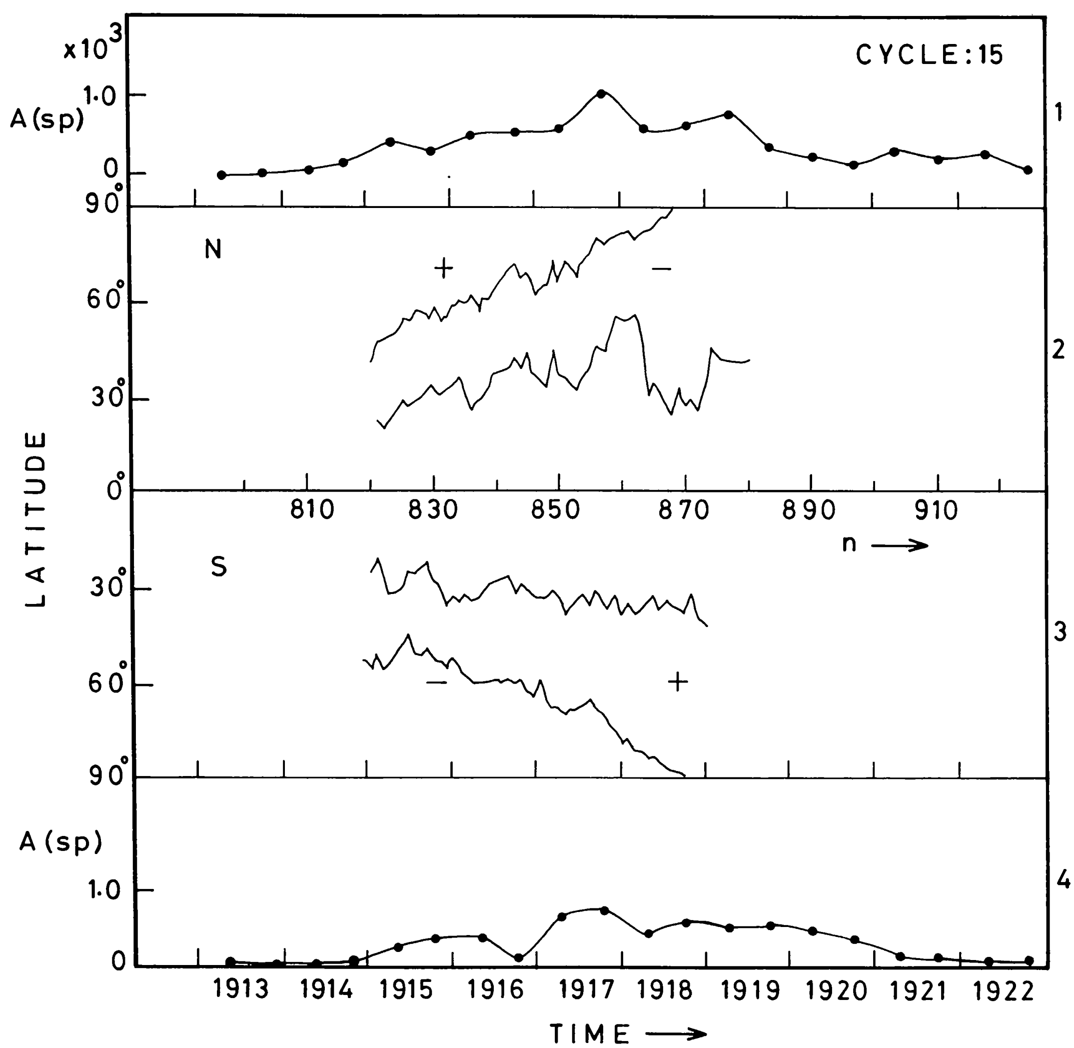

Fig. 3. Same as Figure 1 for cycle 15.

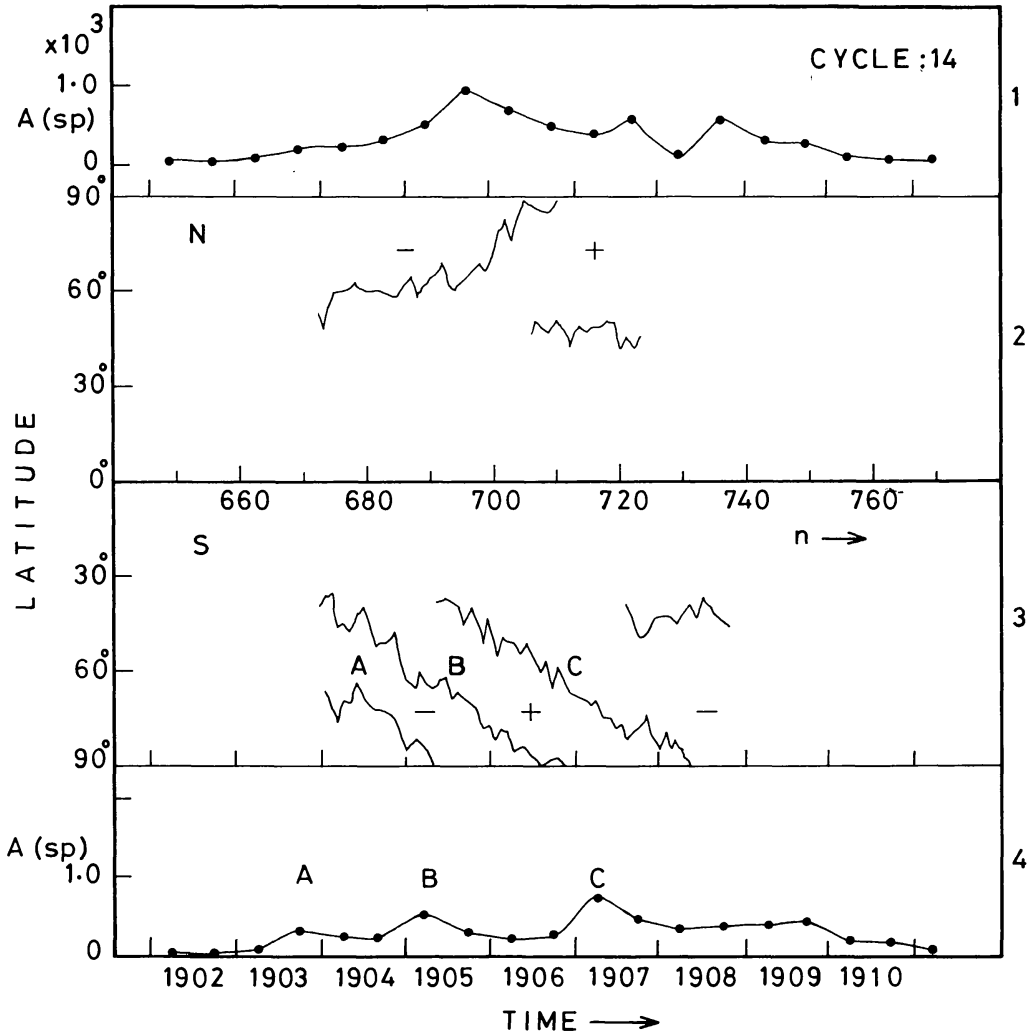

Fig. 4. Same as Figure 1 for cycle 14.

mean velocity of drift was 5.8 m s^{-1} and the polarity reversal took place in 1906.8, about 1.1 years after the peak of the solar activity. In the southern hemisphere, there were three filament bands. The first one (A) reached the pole in 1905.3. The second band (B) which was at latitude 50° in 1904.8 reached the pole in 1906.8 with a velocity of 6.4 m s^{-1} and the third band (C) reached the pole in 1908.4 causing the final polarity reversal for this cycle. Box 4 of Figure 4 shows that the activity took place in three bursts with $C > B > A$. The Sun showed the monopole for two spells 1905.3–1906.8 and 1906.8–1908.4.

4. Summary and Discussion

(1) Using the poleward migration of the magnetic neutral line derived from Hα synoptic charts we have determined the epochs of the polarity reversals of the magnetic fields within the latitude belt 50°–90° in both the hemispheres. The final reversal of polarity

TABLE I

The figures inside the table represent the epochs of polarity reversals expressed in years correct to a decimal

Northern hemisphere

Cycle	17	16			15	14
Polarity change φ_N	(+/−)	(−/+)	(+/−)	(−/+)	(+/−)	(−/+)
90°	1940.1	1927.9	1929.3	1929.9	1918.6	1906.8
80°	1938.4	1926.9	1928.9	1929.4	1917.9	1906.2
70°	1937.9	1926.3	1928.1	1929.2	1917.3	1906.1
60°	1937.0	1925.8	1927.5	1929.0	1916.3	1904.9
50°	1936.0	1924.5	1926.6	1928.5	1915.3	–
V (m s^{-1})	4.5	4.6	5.5	8.2	4.5	5.8
T_{min}	1933.8		1923.2		1912.5	1901.7
T_{max}	1937.5		1928.7		1917.6	1905.7
S(sp)	5.0×10^3		3.9×10^3		3.6×10^3	2.9×10^3

Southern hemisphere

Cycle	17	16	15	14		
Polarity change φ_S	(−/+)	(+/−)	(−/+)	(+/−)	(−/+)	(+/−)
90°	1940.0	1928.5	1918.7	1905.3	1906.8	1908.4
80°	1937.6	1927.4	1918.1	1905.0	1906.1	1907.9
70°	1936.7	1926.7	1917.7	1904.2	1905.8	1907.2
60°	1936.3	1926.2	1916.6	–	1905.0	1906.7
50°	1936.0	1925.0	1915.6	–	1904.8	1906.1
V (m s^{-1})	4.5	4.2	4.7		6.4	6.7
T_{min}	1933.5	1923.2	1913.5		1902.2	
T_{max}	1938.4	1927.7	1917.6		1907.1	
S(sp)	5.0×10^3	3.3×10^3	3.0×10^3		2.8×10^3	

φ_N – latitudes in the north hemisphere.
φ_S – latitudes in the south hemisphere.
V is the velocity of migration of the filament bands in m s^{-1}.
T_{min} is the epoch of the minimum of solar activity preceding the cycle in question.
T_{max} is the epoch of the solar maximum. T_{min} and T_{max} are based on unsmoothed six monthly means of the mean daily areas of sunspots.
S(sp) is the early mean of the mean daily areas of sunspots summed up over one solar cycle and expressed in millionths of the visible hemisphere.

over the poles took place after the maximum burst of activity, the lag ranging form 0.5 to 3.4 years.

(2) If our interpretation that the migration of the filament bands is related to the bursts of activity, then, the non-simultaneous occurrence of the maximum phase of

activity in the two hemispheres is reflected in the different arrival times of the filament bands at the poles in the two hemispheres. It is this relative shift in the epoch of the arrival at the poles in the two hemispheres, that causes the apparent monopole situation on the Sun.

(3) During the eight cycles, three times at the northern and one at the southern hemisphere a threefold polarity change is seen within the latitude belt $50°-90°$ (see Figures 3 and 5 of Paper I for cycles 20 and 19 and Figures 2 and 4 of this paper for cycles 16 and 14). In all these cases the respective hemispheres show three bursts of activity of increasing strength with time. Each filament band can be related to a burst of activity. The velocity of the poleward drift of the neutral line ranges from 4 to 29 m s^{-1}. Thus the velocity increases commensurate with the increase in the strength of the burst of solar activity, that filament band corresponding to the highest peak among the three bursts, having the highest velocity among the three bands. Single fold polarity change took place always either when the activity consisted of only one burst or when more than one existed, they were falling in strength with time.

(4) We have seen in Paper I, that at the ascending part of the cycle, the 'islands' formed by the filament and filament channel have an f-polarity within them. The first filament band formed from the poleward boundaries of these 'islands' distinguishes the 'old' and 'new' polarity of the magnetic field. At the next burst of activity a fresh set of filament and filament channels outline 'new islands' enclosing the new active regions in mid latitudes with the p-polarity. The poleward boundaries of these second generation 'islands' form the second band which migrates to the pole if the second burst, to which this is probably related, is more powerful than the first (see cycles 14, 16, 19, 20). In this case the polarity of the polar regions changes and the situation of the monopole starts. Now, at the third burst of activity the filament and filament channels now outline the third generation of 'islands' obviously enclosing f-polarity. In the same way as before, the poleward boundaries of these new islands migrate to the poles and reverse the polarity once again, breaking the monopole situation. If this burst is the most powerful among the three then the third filament which can be related to this also has the highest poleward drift velocity.

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Reference

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