LONG PERIOD MAGNETIC ACTIVITY – 2 to 100 YEARS

(Research Note)

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Applying the maximum entropy method MEM of Burg (see Smylie *et al.*, 1973; Ulrych and Bishop, 1975) to absolute element 20th century mean yearly H and Z component data from world-wide observatories, Currie (1973a, b) found compelling evidence for an approximately 60 yr signal of internal origin, the solar-magnetic cycle SMC at 21–22 yr, and the solar cycle SC at 10–11 yr. Associated with the latter two fundamental periods were two series of harmonics (see bracketed values in Table I). These findings confirmed Russian studies as regards the reality of a 60 yr signal (e.g., Golovkov and Kolomiytseva, 1971) and extended the earlier work of Currie (1966) by obtaining, for the first time, a consistent morphology for the long period geomagnetic spectrum.

In this note we confirm the recent work (Currie, 1973a) by applying MEM to 100 annual values of the aa magnetic activity index of Mayaud (1973) for antipodal north and south hemisphere observatories. Figure 1 presents the MEM amplitude spectrum for the two series where spectral estimates were computed for frequencies $f = m/400$ cpy ($m = 0$ to 200) after removing the mean and linear trends. Spectra were computed for prediction error filter lengths of $N = 30$, 40, and 50 to yield a total of six spectra. The mean period and standard deviation (sd) for peaks in the spectra are presented in Table I. A remarkable feature of Figure 1 is the virtual absence of peaks which cannot be accounted for in a consistent manner and illustrates again (e.g., Bolt and Currie, 1975; Currie, 1974a, 1975) that in detecting weak signals maximum entropy is more effective than conventional techniques. The two spectra are sensibly identical, and applying the conventional Blackman and Tukey method we find that uniformly coherence is unity and phase zero between the records from 2 yr to the longest estimated period (50 yr).

In Figure 1 the signal at 79 ± 3 yr corresponds to the well-known Gleissberg sunspot cycle of 80 yr; a period up to 30% longer has been attributed to this signal (Sleeper, 1972) but the period may be variable and depend on the epoch of the data set utilized as well as inhomogeneity in the data (e.g., see Cohen and Lintz, 1974). No signal at 60 yr is evident which is expected because in deriving magnetic indices base line control of absolute element geomagnetic data is destroyed. The fundamental SMC and SC signals are slightly biased from the nominal values of 22.2 and 11.1 yr. All the remaining peaks, with one exception, fit into harmonic sequences as discussed later.

TABLE I

Observed solar magnetic cycle SMC and solar cycle SC fundamentals with associated harmonic periods as obtained from Mayaud's (1973) aa magnetic activity index. Residuals are based on nominal fundamental periods of 22.2 and 11.1 yr. Bracketed values refer to observations obtained from H component absolute element geomagnetic data (Currie, 1973a)

Harmonic	Period (yr)		Residual (yr)	Period (yr)		Residual (yr)
n	Observed	(Currie, 1973a)	$22.2/(n+1)-$Obs	Observed	(Currie, 1973a)	$11.1/(n+1)-$Obs
0th	22.9 ± 2.0	(21.4)	−0.70	11.5 ± 1.0	(10.5)	−0.40
1st	11.5 ± 1.0	(10.5)	−0.40	5.58 ± 0.22	(5.15)	−0.03
2nd	6.93 ± 0.07	(7.10)	0.47	3.37 ± 0.01	(3.39)	0.33
3rd	5.58 ± 0.22	(5.15)	−0.03	2.75 ± 0.01	(2.74)	0.02
4th	4.35 ± 0.03	(4.35)	0.09	2.11 ± 0.00	(2.15)	0.11
5th	3.75 ± 0.03	(3.71)	−0.05			
	3.37 ± 0.01					
6th	3.08 ± 0.00	(–)	0.09			
7th	2.75 ± 0.01	(2.74)	0.02			
8th	2.40 ± 0.01	(2.38)	0.07			
9th	2.27 ± 0.01	(2.15)	−0.05			
10th	2.11 ± 0.00	(–)	−0.09			

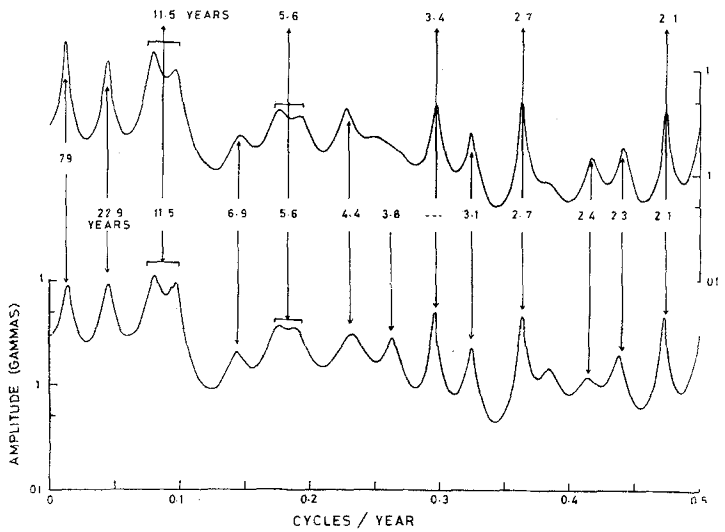

Fig. 1. Maximum entropy spectra for $N=40$ using Mayaud's (1973) aa magnetic activity index. Upper and lower spectra are from antipodal northern and southern hemisphere time series, respectively.

Figure 1 illustrates the broad band structure from about 9 to 14 yr of the SC peak which reflects the highly variable period of individual cycles. We attach little significance to the periods of the doublet peaks within the SC band because a single broadband peak splits into two or more multiplets if N is taken too large (see Figure 1b of Ulrych and Bishop, 1975; Currie 1974b, 1975) and no objective criterion to truncate N that is effective is yet available. Our present results illustrate this: for $N=30$ the SC is a singlet that bifurcates into a doublet (mean periods of 10.5 and 12.5 yr) for $N=40$ and 50; for $N=30$ and 40 the SMC is a singlet that bifurcates for $N=50$ (mean periods of 20.2 and 22.5 yr).

The detailed and interpreted results of our study are displayed in Table I. The observed mean periods and sd are generally in close agreement with the bracketed values obtained using H component absolute element data (Currie, 1973a). For the SMC signal the residuals of observations from those obtained with a nominal 22.2 yr signal are generally less than 0.1 yr. Reconstructing the fundamental by multiplying harmonics by $(n+1)$ yields only one value (6.93) outside the range 22.9 ± 2.0 yr. The major difficulty in the interpretation is that in Table I (and Figure 1) the strong peak at 3.37 ± 0.01 yr must be left out of the SMC harmonic series.

Results for the SC are in the last two columns of Table 1. The only major difficulty is that again the 3.37 yr peak is anomalous: the residual is 0.33 yr whereas for other harmonics residuals are generally less than 0.1 yr; also, a reconstructed fundamental using $(n+1)3.37$ is outside the range 11.5 ± 1.0 yr. We have nevertheless interpreted this peak as the 2nd harmonic because in Figure 1 it is a strong peak and similarly agrees with results from H component data (Currie, 1973a).

Currie's (1973c) sunspot spectra are poor because in the light of extensive subsequent experience I believe N was chosen too high. My emphasis on multiplet structure must be discounted, the marginal evidence for a 60 yr signal rejected, and it is likewise extremely doubtful if the SMC exists in sunspot numbers. However, Currie (1973c) does find significant power from about 8 to 15 yr in the sunspot spectrum and relatively good evidence for the first four harmonics of the nominal 11.1 yr signals. Interestingly, Currie (1973c) also finds peaks within the SC band at 8.3, 10.0, and 11.1 yr in agreement with Cohen and Lintz (1974), but we are now sceptical that the triplets are significant.

In summary, the results obtained from Mayaud's (1973) aa index support Currie (1973a) as regards the two series of harmonics for the SMC and SC. The major difficulty is the strong anomalous signal at 3.37 yr found in both studies. The varied implications in geophysics and space physics of such harmonics are discussed by Currie (1973a).

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