PRESENCE OF PERIODICITY IN METEORITE FALLS

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Abstract: A maximum entropy method (MEM) spectral analysis is made of the number of historically recorded meteorite falls in China from AD 619 to 1943 and the number of witnessed falls in the world during the period from 1800 to 1974. The presence of a 60 year period as suggested by previous workers, CHANG and YU (Mem. Natl Inst. Polar Res., Spec. Issue, **20**, 276, 1981), is confirmed as a common feature of meteorite fall rate. In this paper the period is determined to be between 60 and 63 years. A periodicity of 240 years, also previously noted, is unstable in spectral analysis, suggesting that this periodicity may not exist. The presence of two more periodic components: ~10.6 years and ~17.7 years in meteorite flux is indicated from the power spectrum.

1. Introduction

There exists in the Chinese historical records, a large set of systematic records on meteorite falls, which can be used as a valuable data set. In the previous paper, CHANG and YU (1981), made a time series analysis of the annual number of recorded falls by calculating an autocorrelation function, and found two cyclic periods; 240 years and 60 years. In this work, we made a spectral analysis of the same data by means of the maximum entropy method (MEM) of BURG (1967), in order to deduce a more accurate estimate of the periodicity in meteorite falls.

2. Method of Spectral Analysis

The original version of MEM by BURG (1967) possesses some instability in the computed spectrum (peak splitting, systematic shift of peak position, etc.). A number of later improvements of MEM have been made (*e.g.*, FOUGERE, 1977; SAITO, 1978; SWINGLER, 1979); among others, Marple's algorithm (MARPLE, 1980) employing a non-Toeplitz form (ULRYCH and CLAYTON, 1976) appears to give a reasonably stable and accurate spectrum. We have tested both BURG's and MARPLE's methods for the present data, the difference between them was minimal, and for this paper have chosen BURG's algorithm.

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Another crucial problem in MEM is the choice of an AR order or an appropriate length of prediction error filter. If an AR order is selected that is too large, it results in many spectral peaks that may be false. An information criterion (AIC) proposed by AKAIKE (1970) does not appear useful for limiting an AR order. It results in an AR order that is too short for a time series, with many spectral components superimposed on random noise of large power. In this work we have employed a larger AR order than that given by AIC, so as to recognize periodicity that may be present in meteorite fall data. If a commom periodic component is recognized in the individual data sets, we may then consider it significant in the meteorite fall rate.

3. Data

The number of recorded meteorite falls, in 5 year intervals, from AD 619 to 1943 in China are shown in Fig. 1. The data are divided into three segments of equal length

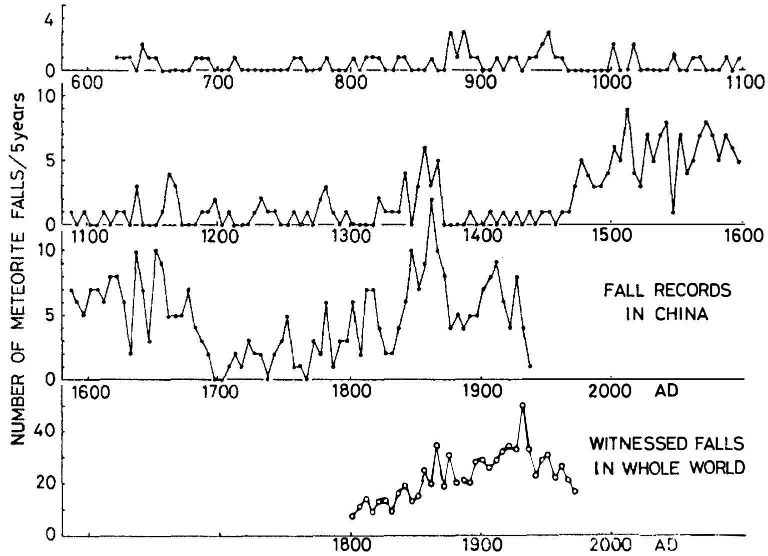

Fig. 1. Numbers of meteorite fall records in China (AD 619–1943) and of witnessed falls in the whole world (AD 1800–1974) in 5 years.

(465 years); (1) early period of ancient China (AD 619–1083), (2) later period of ancient China (AD 1009–1473) and (3) recent China (AD 1474–1943). The first two segments are overlapped by 74 years or 16%. A spectrum analysis also was made on the number of witnessed meteorite falls in the world (AD 1800–1974), shown in Fig. 1. The gradual increase of witnessed falls in the 19th century appears to be due to cultural effects, whereas a systematic decrease in the number of recorded falls since the 1940's undoubtedly indicates that the actual number of meteorite falls is decreasing. This feature together with the low rate of fall in China during the 18th century provides evidence that the rate of meteorite falls is not steady over time.

It is noted, however, that one must be very careful about the cultural, social and artificial effects on data relying on human observation. For example, the annual number of reported volcanic eruptions is reported to be dependent on the social conditions (see *e.g.*, SIMKIN *et al.*, 1981).

4. Results

The MEM power spectra with two different AR orders are shown in Fig. 2 for four data sets. The spectrum of late China (AD 1009–1473) is similar to that of the entire ancient China (AD 619–1473), because the number of recorded falls in the former is a dominant fraction of the latter. The power spectrum viewed on logarithmic scale as a whole is flat, suggesting that the spectrum is white. However, we can recognize several spectral peaks superimposed on the white noise. The peak frequencies are shown by period (year/cycle) in Table 1. It is noted that each figure in the table is not accurate.

Although the presence of a 60 year period found by CHANG and YU (1981) appears to be common to all data sets, it can not be determined if this is an accurate period. Our data indicate that the period is between 60 and 63 years.

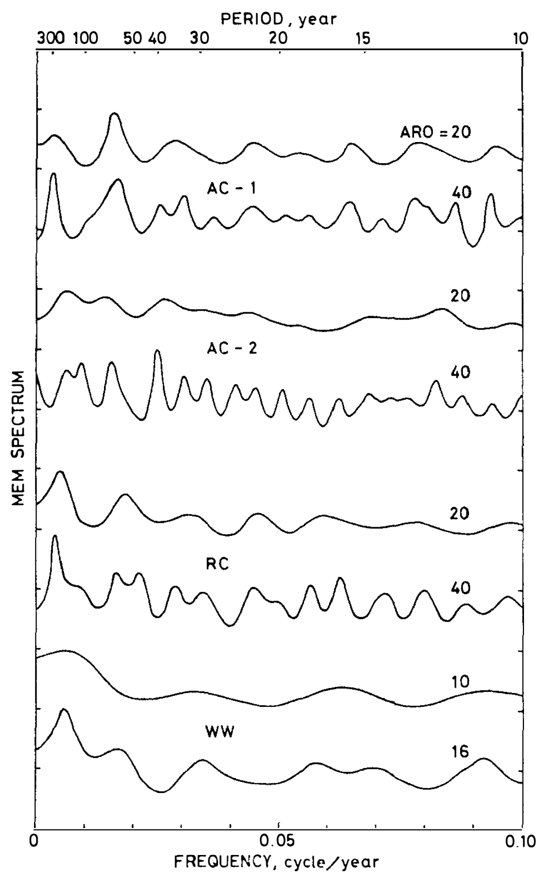

Fig. 2. Logarithm of MEM power spectra (vertical unit = 1 order) of time series in Fig. 1.

AC-1 (AD 619–1083), AC-2 (AD 1009–1473), RC (AD 1474–1943): China, data length = 93.

WW: whole world (AD 1800–1974), data length = 35.

ARO: autoregressive order = number of AR parameters less unity.

Table 1. Detected period by MEM spectrum of meteorite falls. Comparison is made with the integer multiple of the period of Jupiter's orbital motion.

Detected period, year				Integer multiple N of Jupiter's period year	
China			Whole world		
Ancient		Recent			
619–1083	1009–1473	1474–1943	1800–1974	11.862N	N
10.7	10.6	10.3	10.8*		
11.6	11.4	11.3		11.86	1
	12.1*	12.5			
13					
	14.7	13.9			
15.4*	16.0	16.0*			
	17.7	17.7*	17.7	17.79	1 1/2
	19.6	20			
22.5	22.0	22.6*		23.72	2
	24.3				
	28.2	29			
	32.6		30	29.65	2 1/2
33*		35		35.58	3
40	39.5*			41.51	3 1/2
		47		47.44	4
61*	63.5	61*	60*	59.31	5
	105	110		118.62	10
	175		175*	177.93	15
		265*		237.24	20
290				296.55	25

* Significant peak.

The spectral power is large at very low frequency range. A cycle of 240 years suggested by CHANG and YU (1981), is not supported by the data presented in Fig. 2 and Table 1. None of the four detected periodicities at ~110 years, ~180 years, ~265 years, and ~290 years, are common to more than three data sets. The existence of such low frequency components is certain, as inferred from Fig. 1, but their stability is questionable. The detailed spectral structure of these components is a subject of future study.

The remaining spectral peaks are not stable enough to convince us they are stationary components, with the exception of those at ~10.6 (10.3–10.8) years and ~17.7 years, which are common to the three latter data sets. The non-stable spectral peaks can not be identified with the higher harmonics (30, 20, 15 and 12 years) of a ~60 year cyclic component. We believe it is possible that the meteorite fall rate contains periodicity of ~10.6 years and ~17.7 years. Statistically the other spectral peaks may be regarded as originating from a random noise component, although the possibility can not be discarded that the actual meteorite fall rate has some periodicity of a non-stationary feature; *e.g.* amplitude-modulated.

5. Discussion

An MEM and its modified methods are a powerful technique for analyzing the spectral structure of data given as a finite time series. However, it has been cautioned that a black-box application of such a parametric spectral estimation may lead to a false conclusion. During the present analysis of the meteorite data, the Nagoya group of authors has discovered a new method of spectral analysis with higher resolution and an improved method to interpret the stability of spectral peaks. This new technique is now being applied and will be reported, when a useful conclusion is reached.

The Beijing group of authors surmises that there is a correlation between the observed meteorite periodicity and Jupiter's period of orbital motion, as a result of celestial-dynamic perturbations. The detected periods of ~ 60 years and ~ 17.7 years are approximately 5 and 1.5 times that of Jupiter's period (11.862 years), respectively. We see similar commensurability for other spectral peaks with Jupiter's period. Although this suggestion is interesting, additional studies on meteorite fall data are necessary to advance this hypothesis further.

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