PREDOMINANT PERIODS IN THE TIME SERIES OF DROUGHT AREA INDEX FOR THE WESTERN HIGH PLAINS AD 1700 TO 1962

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ABSTRACT

The detection of the combined presence of the Hale magnetic sunspot cycle (22.28 years) and the lunar nodal tidal cycle (18.61 years) in both the Eastern North American January air temperatures and the Western U.S. High Plains drought series has led to an extended analysis of the Drought Area Index time series. This analysis indicated that the mean dominant period of the drought series should be 20.0 to 20.5 years and that the principal period should be resolvable into two components of about 22.28 and 18.61 years. This note details the successful accomplishment of this task.

INTRODUCTION

The historical record of droughts in the United States Western Plains has been extended by the use of tree ring records by Mitchell, Stockton, and Meko (1), hereafter designated MSM. The tree ring data for 40 areas were evaluated from AD 1700 to the end of the tree ring library in 1963. This time series was calibrated to correspond to the instrumental Palmer Drought Severity Index (PDSI) in the time interval of overlap, between 1931 and 1963 (1). MSM studied this calibrated time series, called the Drought Area Index (DAI), for periodicities using discrete Fourier transform analysis. They interpreted the spectra as indicating a principal period of 22 years. They also performed filter analysis of the series corresponding to Palmer Drought Severity -1 (mildly dry) or worse (up to -4 [extremely dry]) with broad bandpass filters with center periods of 20.6 and 24.3 years and with a low pass filter. All the filter results were quite similar, showing a series of rather regular undulations. The timing of the peaks is an indication of periods of drought and the amplitude of the waves is an indication of drought intensity. The timing of the waves shows a good correlation with the Hale magnetic sunspot cycle and the amplitudes show good correlation with the envelope of the Zurich sunspot number (an indicator of general solar activity).

Recently Bell (2) has re-examined these results and the spectral and filter studies of the January mean surface air temperatures in Eastern North America (Mock and Hibler [3]). Bell demonstrated the presence of a beat note effect in both time series. This beat effect indicates the presence of two oscillations of comparable frequency and amplitude. The two periods found in the DAI series--by considering the gross period of the undulations and the number of waves between the two beat oppositions--were about 22.21 and 18.51 years. Bell suggested these periods were the 22.279 year Hale magnetic sunspot period determined by Dicke (4) and the 18.61 year lunar nodal tide cycle. The gross period, determined by counting the waves and the time span they covered (2), of the oscillations in the filtered DAI series of MSM was about 20.36 years.

It seemed worthwhile to reexamine the DAI time series using the higher resolution Maximum Entropy Spectrum Analysis (MESA) method to see if the two component periods could be resolved. Also, the DAI series constructed by MSM forms an amplitude scale that is quite non-linear since each of the 40 areas of the High Plains is counted as having either drought condition -1 or worse or else no drought for each year. In this way if the drought is more severe in an area it does not affect the total index for that year beyond 1 unit. We thought that the non-linearity of response might have biased the contribution of the component periods and distorted the spectral results.

DATA ANALYSIS

Through the kind cooperation of Dr. J. Murray Mitchell Jr., the Drought Area Index time series was made available for study. An effort was made to reduce the nonlinearity of the DAI series by forming a linear combination of the DAI indices -1 to -4. The value at the i-th year of the combined series is:

$$DAI(i) = A_{-1}*DAI\text{-}1(i) + A_{-2}*DAI\text{-}2(i) +$$

$$A_{-3}*DAI\text{-}3(i) + A_{-4}*DAI\text{-}4(i)$$

where the A's are weighting factors.

We do not know what values of the A's would produce a linear "drought" function, due as much to a lack of knowledge of a linear scale of "drought" as to the relation of drought scale to the Palmer Drought Severity Index from which the DAIs were calibrated. In our ignorance we let all of the A's equal 1. Although this choice is quite arbitrary, it gives a better approximation to a linear scale since the value for an area may now increase as drought becomes more severe in that area.

A new time series was formed from the MSM series in this manner. To remove some of the high frequency noise, the series was then smoothed slightly by two passes of 1-2-1 smoothing, that is, for each pass:

$$DAISS(i) = [DAIS(i-1) + 2*DAIS(i) + DAIS(i+1)]/4$$

The mean value of the series was then removed from each DAISS(i) value. The resulting series is shown in Figure 1. Similar smoothing and average removal were applied to the original DAI-1 series of MSM.

Both of these time series were subjected to MESA. The results from both were quite similar. When short predictive filter lengths were used (L=24 to L=50) the principal peak was single-valued. At a filter length of 40 (Figure 2), the peak had a period of 20.04 years for the original DAI series and 20.23 years for the "more linear" DAISS series. At a filter length of 60 elements the principal peak was resolved into two components for both series. Figure 3 shows the spectrum for the "more linear" series at a filter length of 60, while Figure 4 shows an expanded section around the principal peaks. The periods of 22.07 and 18.60 years were found to be in good agreement with the expected values of 22.28 and 18.61 years (2). The original DAI series at a filter length of 63 gave component values of 22.03 and 18.23 years.

The filter lengths needed for resolution lie well below both the appropriate length for a short or noisy series at N/2(=131) recommended by Ulrych and Bishop (5) and the length for longer series at 2N/ln(2N)(=84) recommended by Berryman (6).

CONCLUSION

In conclusion, the high resolution MESA spectra provide evidence that the DAI time series is dominated by two principal oscillations that seem to correspond to the Hale magnetic sunspot cycle and the lunar nodal tidal cycle, in agreement with the findings of Bell (2). However, there is only a small change in the periods as the linearity of the DAI series amplitude scale is improved. The spectra (Figures 3 and 4) show that the lunar tidal cycle is considerably weaker than the solar cycle, on the average, but as a result of the considerable variability of the sunspot envelope, the amplitude of the lunar cycle was slightly greater at the beat opposition in 1880.

REFERENCES

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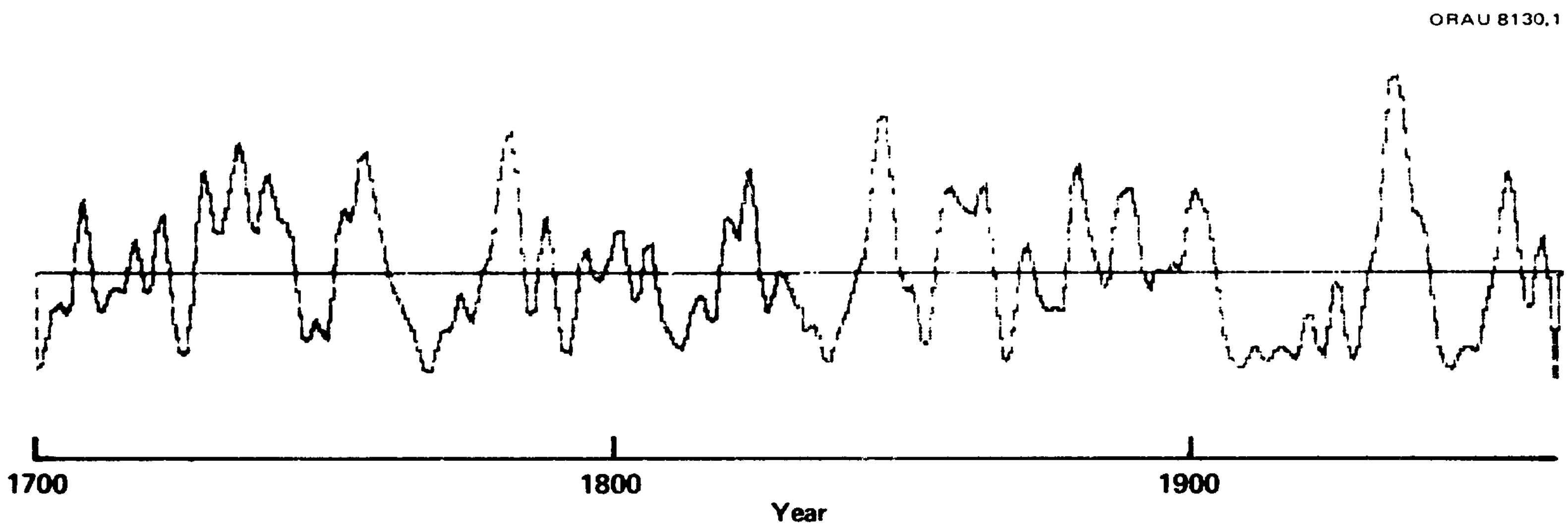

Figure 1. A more linearized Drought Area Index series for those areas out of 40 that had drought from mildly dry to worse from 1700 to 1962. The series has been smoothed by two passes of a 1-2-1 smoother.

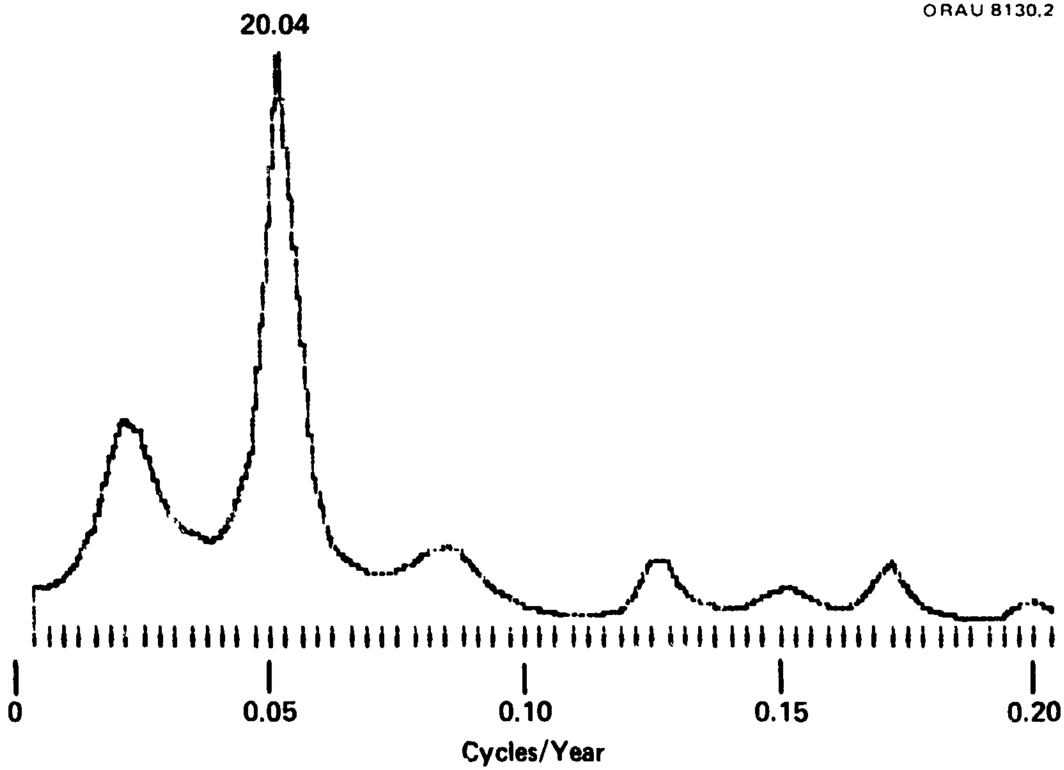

Figure 2. Maximum Entropy spectrum of the original DAI series at a filter length of 40 elements. The principal peak has a period of 20.04 years.

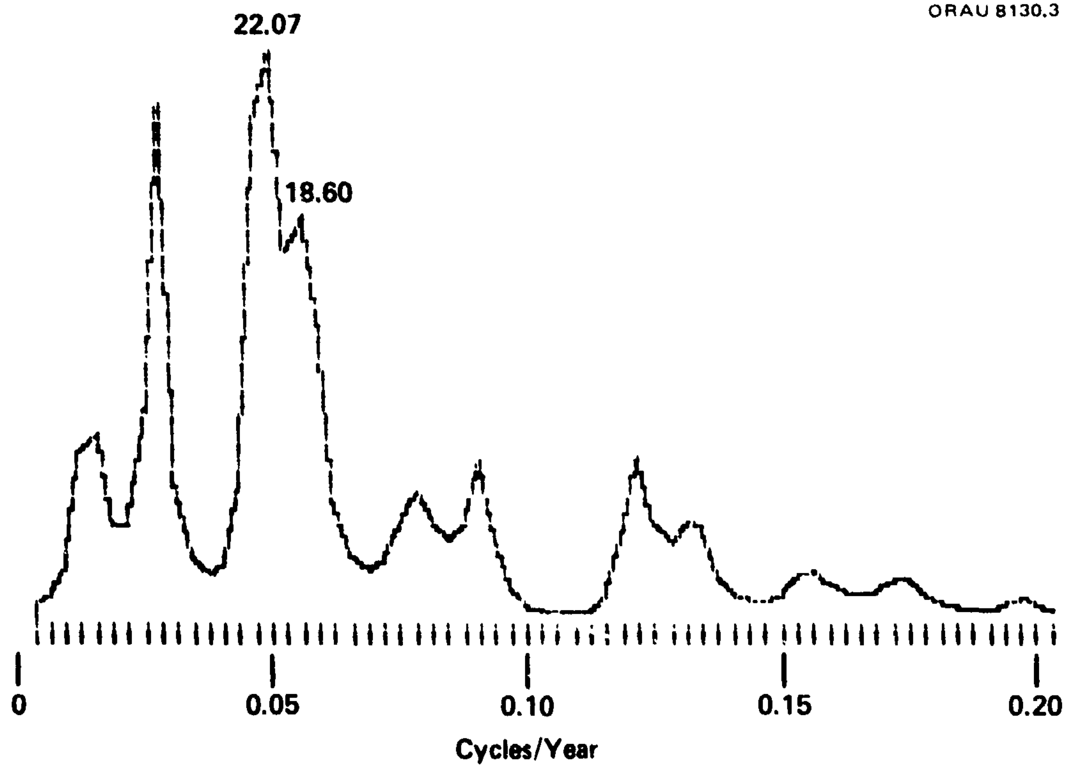

Figure 3. The MESA spectrum for the "more linear" DAI series at a filter length of 60 elements. The principal peak has been resolved into its two components of 22.07 and 18.60 years in good agreement with the 22.28 year Hale magnetic sunspot cycle and the 18.61 year lunar nodal tide cycle.

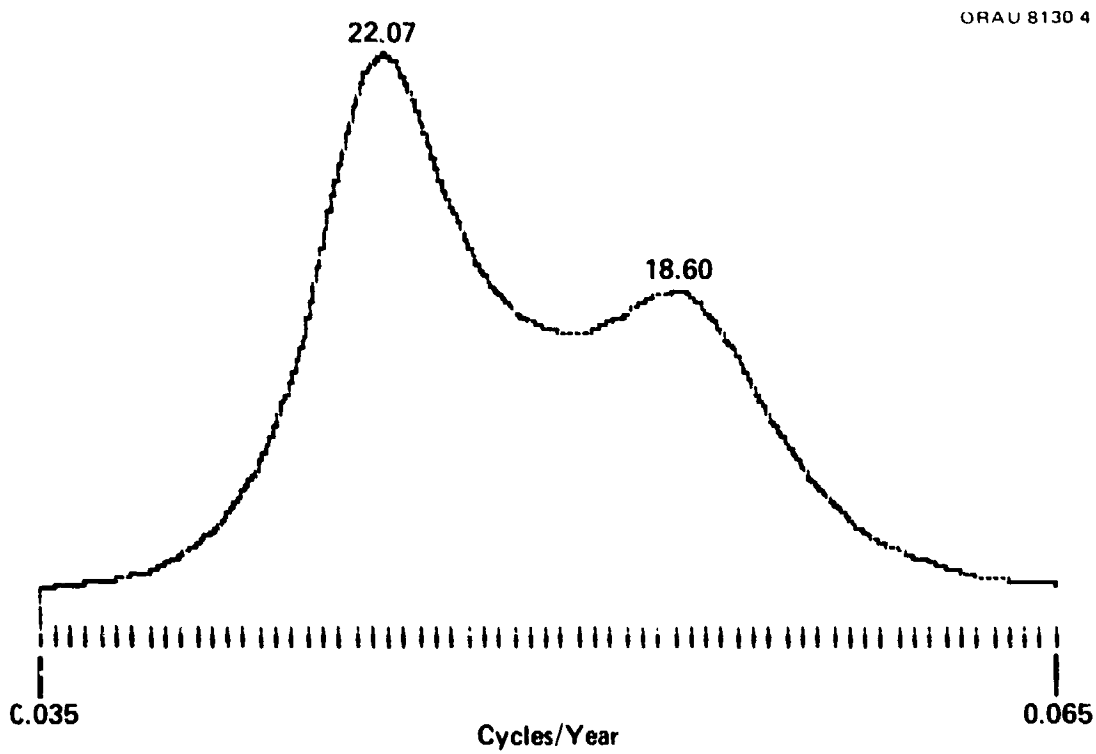

Figure 4. A section of the MESA spectrum of Figure 3 expanded