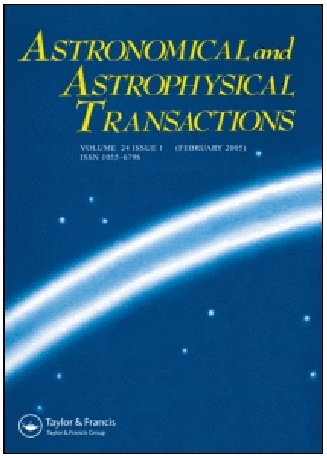

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PROGNOSIS OF THE NEXT TWO SOLAR CYCLES

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A new method of long-term solar activity forecasting based on one-step extrapolation of the Walsh presentation of the Wolf numbers is used to predict the 23rd and 24th solar cycles.

KEY WORDS Solar cycles, solar activity, Wolf numbers, prognosis

Wolf numbers present a finite and discrete set of data for a given solar cycle. Therefore in principle they can hardly be represented by the usual Fourier transformation. In such a case it is better to use the transformation with a finite set of basis functions as, for example, Walsh or polynomial transformations.

The Walsh functions arranged after Grey's code were used in this work to present the monthly mean Wolf numbers W averaged over the 32 equidistant phase points of each of the last 22 cycles, considered as an interval between two successive minima. This gives 22 sets of 32 Wolf numbers.

Let $W(m)$ be the monthly mean Wolf number as a function of the month number m in the cycle under consideration. As the main characteristics of each cycle let us take the mean value PL (the process level) and dispersion SP (spectral power) of the Wolf number in the cycle. By definition PL is the first Walsh coefficient K_0:

$$\mathrm{PL} = \frac{1}{T}\sum_{m=1}^{T} W(m)$$

and

$$\mathrm{SP} = \sum_{n=1}^{M} K_n^2 = \frac{1}{T}\sum_{m=1}^{T}[W(m) - \mathrm{PL}]^2 = \sigma_W^2, \tag{1}$$

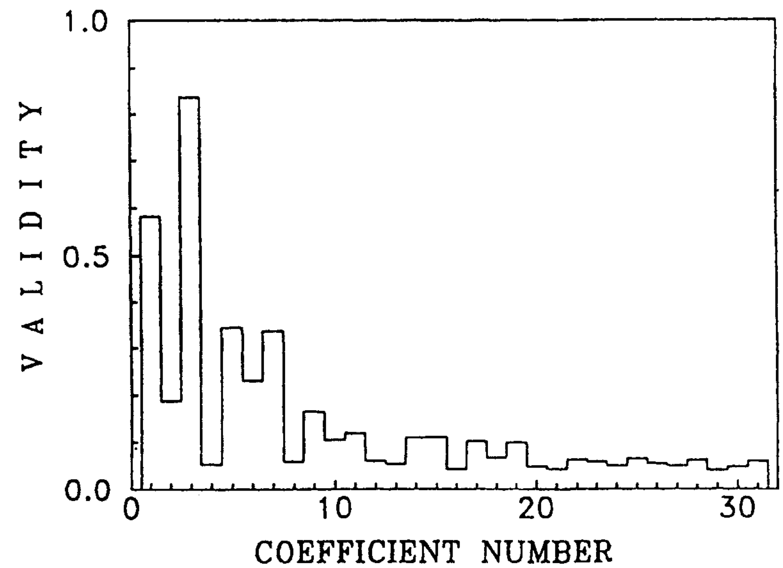

Figure 1 The dependence of the validity of the coefficient on its number.

where T is the number of months in a given cycle, $M = 32$ and K_n are the coefficients of the Fourier–Walsh expansion representing the data values

$$W(t) = \sum_{n=0}^{\infty} K_n \cdot \psi_n(t),$$

where $\psi_n(t)$ are the basic Walsh functions. As a result

$$K_n = \int_0^{2\pi} W(t) \cdot \psi_n(t)\,dt, \text{ and } t = \frac{2\pi m}{T}.$$

From the last formulae one can see that the value t is the cycle phase. The 32 Walsh coefficients K_n simply represent the exact values of the 32 accepted Wolf numbers, $W(t), t = 1, 2, \ldots, 32$. In each cycle the absolute value of the K_n decreases as the number n rises. The values of some coefficients K_n change significantly from cycle to cycle so these coefficients are very important for the purposes of prognosis.

According to Chumak et al., (1989) the validity Z_i for a coefficient K_i is determined as $Z_i = (|K_i| + |\Delta K_i|)/\sqrt{SP}$, where all values are assumed to be mean values for all 22 known cycles (Figure 1).

There are two groups of Walsh coefficients specific to the Wolf number presentation. The first one is characterized by large Z values and regular dependence of the coefficients upon the cycle number (e.g., SP, PL $= K_0$, and the coefficients K_1, K_2, K_3, K_5, K_6, K_7); the other group incorporates all remaining coefficients characterized by low validity and small irregular variations.

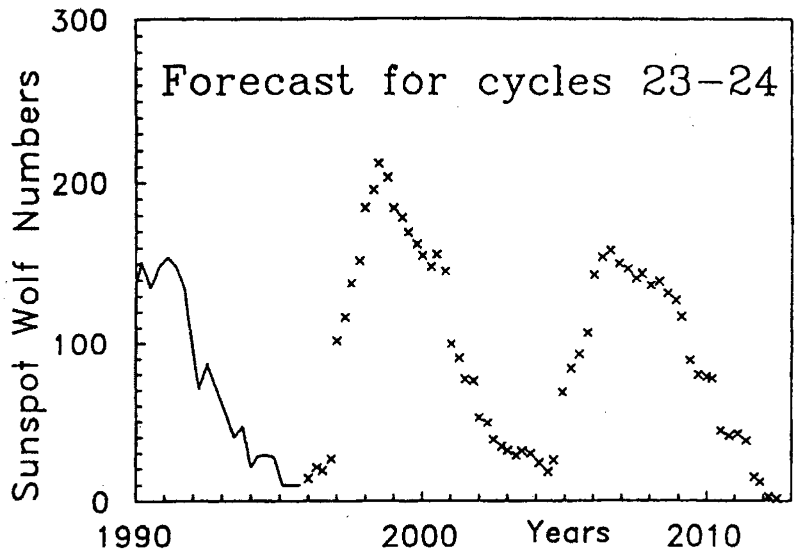

Figure 2 Wolf number forecasts for cycles 23 and 24.

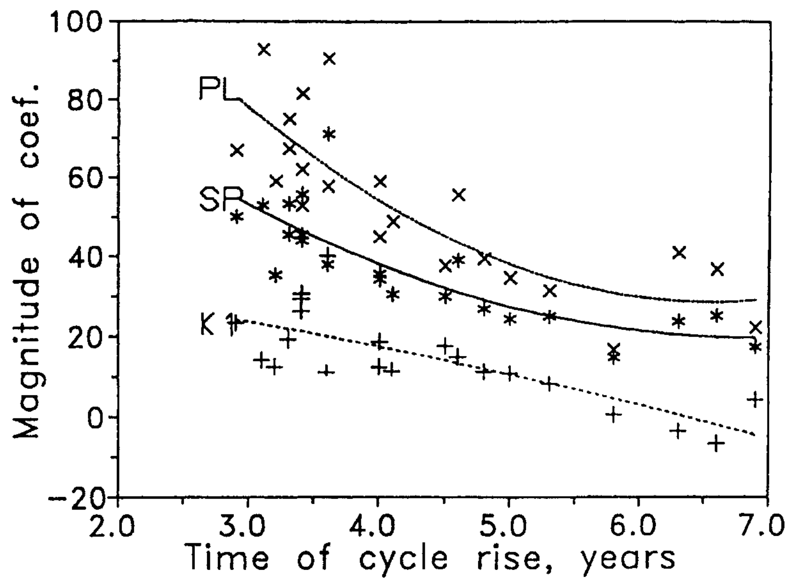

Figure 3 The statistical dependence of $\sqrt{\mathrm{SP}}$, PL and K_1 on the length of the cycle rise.

The large-scale properties of the 11-year cycles are presented by the first group of coefficients. The spectral information about solar activity fluctuations is given by the second group of coefficients.

The accurate one-step extrapolation of the first eight coefficients K_0 to K_7 assuming average values for all the others, permits us to derive the prognostic values of the coefficients for the required cycle. Its Wolf numbers are easy to obtain by the inverse Walsh transformation. This procedure made separately for odd and even cycles permits us predict a pair of future cycles.

About two dozen approximate relations between the main coefficients were revealed to improve the predicted set of coefficients. Such numerous conditions to be fulfilled provides the possibility of obtaining a narrow interval of limits for the required values.

An interesting relation was discovered between the spectral power and the process level, namely $\sqrt{\mathrm{SP}}/\mathrm{PL} = 0.7$, accurate up to 2% for all known cycles.

Formulae (1) were used to prove self-consistent results; these formulae mean that the coefficients incorporate all of the primary information and nothing more.

The resulting forecasts of the Wolf numbers for cycles 23 and 24 are shown in Figure 2. The real time values were scaled using the cycle phases and the relations shown in Figure 3 instead of the usually accepted Waldmeier formulae. The coefficients K_0, K_1, and $\sqrt{\mathrm{SP}}$ turned out to correlate with the cycle rise duration length t_1 with a 70% level of significance.

The epignoses were analysed to reveal that the Wolf number arrays provide information sufficient to predict only those cycles which display "ordinary" behaviour because the method itself can reveal only appropriate behaviour, not "falling out of step". External information is neccessary to get good forecasts in these cases.

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