SHORT-PERIOD CYCLIC VARIATIONS OF SOLAR ACTIVITY AND THEIR GEOPHYSICAL CONSEQUENCES

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Summary. Spectral analysis of the geomagnetic index Aa and Wolf number W has been made. The authors assume that solar activity and geomagnetic field have the common cyclic variations of 2, 3.5 and 5.5 year.

Key words. Wolf number-geomagnetic index.

1. INTRODUCTION

In this paper we are dealing with the cyclic variations of solar activity and geomagnetic field in the range of periods 1—10 years. In the scientific literature short-period cycles of solar activity are not convincingly proved (Lamb 1972). There are, even, the contradictory opinions about their existence. For example, Djurović (1981, 1983) assumes that solar activity causes several short-period variations of the geomagnetic field, the atmospheric angular momentum (AM) and the angular velocity of the Earth-rotation (ω). However, Wallenhorst (1982), analysing the spectrum of W, considers that Djurović's assumption is less probable.

In the mentioned papers of Djurović, the Wolf number W, the geomagnetic index Ap and the difference between universal time scales UT2-TAI were analysed. With the aim to reexamine the same conclusions, with the additional arguments, in this paper will be analysed the serie of the monthly means of the geomagnetic index Aa for the period 1868—1977, published in IAGA Bulletin No 32h, 1978. Besides Aa, the serie of monthly W for the period 1944—1979 will be re-analysed by somewhat different methods than earlier.

2. THE SPECTRA OF Aa

Let ΔAa be the residuals defined by:

$$\Delta Aa = Aa - P_3,$$

where P_3 represents the secular term, approximated by the 3rd order polynomial.

The sum of secular and long-period terms of Aa was successively represented by the polynomials P_n for $n = 1, 2, 3, \ldots$ and for each order n the standard deviation (σ_n) has been computed. In this way we have seen that for $n > 3$, σ_n practically does not decrease.

In Fig. 1, where Aa is presented, the dotted line corresponds to P_3.

The spectra of ΔAa, computed by the method of direct Fourier transforms (DFT), for the whole interval 1868—1977 and, afterwards, for three 36-yr subintervals are plotted in Fig. 2.

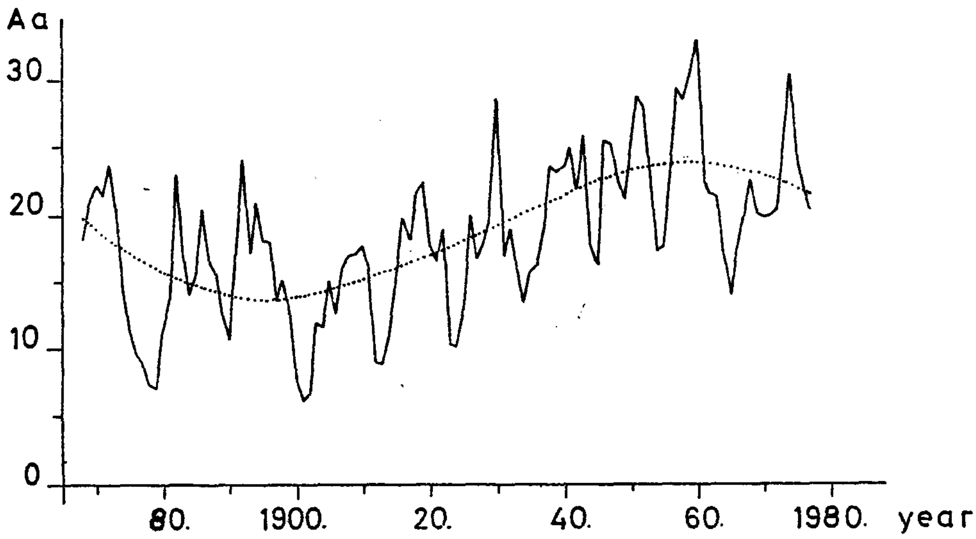

Fig. 1: The geomagnetic index Aa

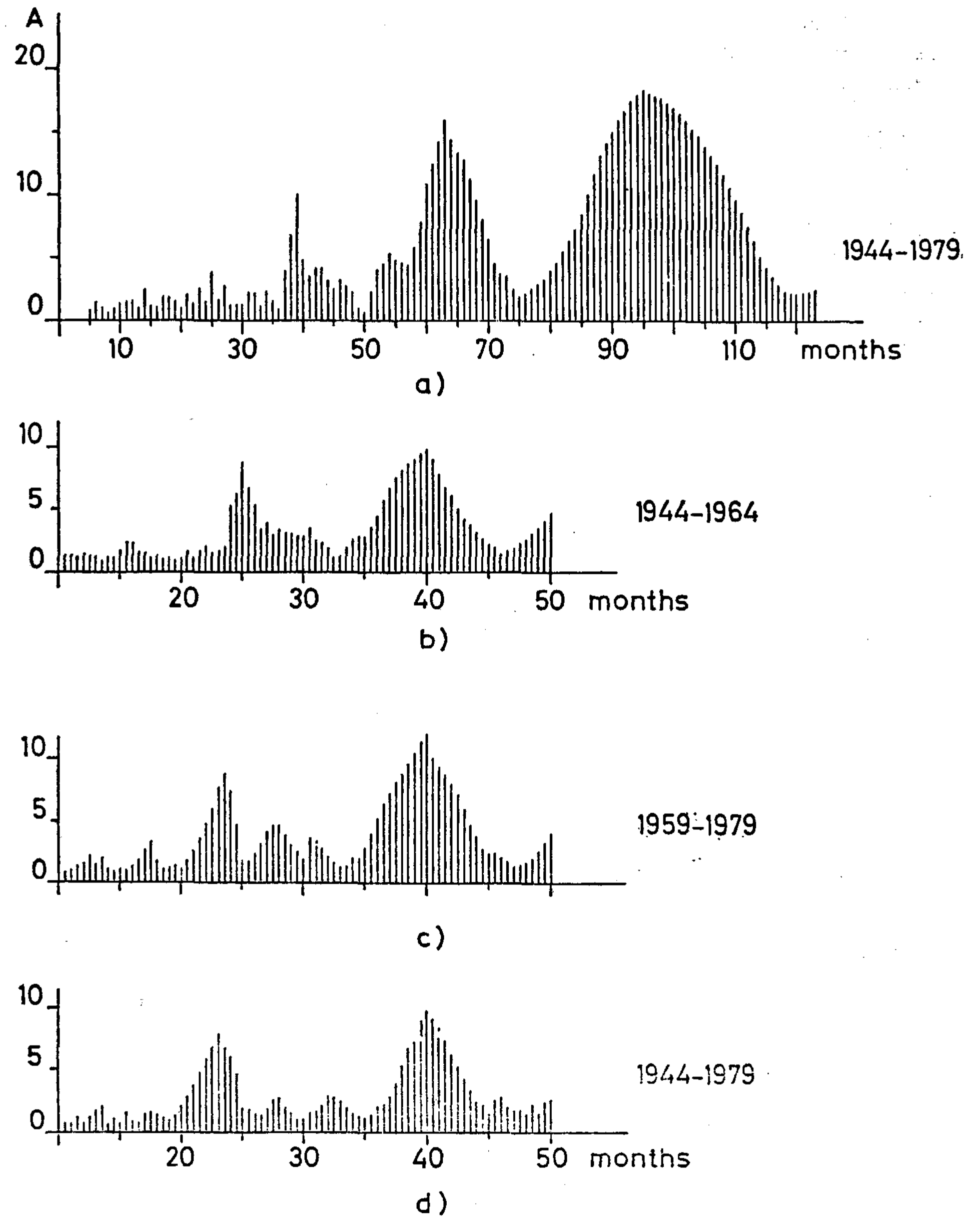

Fig. 2: The spectra of residuals ΔAa

Having intended to present the simplest information about the cyclic structure of W and Aa and about the amplitude/noise ratio, in the figures of this paper the square root of the power spectrum (or amplitude A) was plotted on function of a period P.

In each spectrum in Fig. 2 the peaks of 6, 23, 40 and 65 months have been remarked. In the former one there is a pronounced 11-yr peak more.

The 6-mth and 11-yr cyclic variations of Aa were well known earlier. Besides, spectral analysis of Aa suggests that there exist the cycles with the characteristic periods of 2, 3.5 and 5.5-yr.

The numerical values of the period P, the amplitude A and the phase F of cycles mentioned above are given in the Table I.

Since Aa depends on the corpuscular solar radiation, coming from the active centers (AC), situated over sunspots or in their vicinity, the results in Fig. 2 and Table I suggest the comparative analysis of the spectral pictures of Aa and W.

3. THE SPECTRA OF W

The data used for this analysis are monthly means of W for the period 1944—1979, published in »Astronomische Mitteilungen der Eidgenössischen Sternwarte Zürich« and »Quarterly Bulletin on Solar Activity«.

A great problem in the investigation of the cyclic structure of W represents the existence of its non-cyclic fluctuations. Because of their great amplitude, in the spectra appear the secondary maxima of the non-negligable amplitudes. This problem is less emphasized in the case of spectra of the geomagnetic index Aa or Ap.

In order to avoid the secondary maxima of 11-yr cycle, which could mask weak cyclic variations of W (if they exist), the spectrum of residuals:

$$\Delta W = W - P_n - S$$

was often analysed.

In the last equation, P_n represents a polynomyal term of W (somebody puts $P_n \equiv 0$), S — the 11-yr sinusoïde, computed by the least-squares method (LSM).

This way of eliminating the 11-yr cycle is not always satisfactory. For example, in the spectrum of ΔW (Fig. 3a), computed by DFT method, the peak of 11-yr is dominant, despite the fact that S has been subtracted.

As it can be seen in Fig. 3a, the peaks of 3.5 and 5.5-yr are well emphasized, while the 2-yr peak does not exist. However, it is pronounced in two spectra of ΔW computed over 20-yr subintervals (Fig. 3b, c). This situation is probably due to the great non-periodical fluctuation of W, less emphasized in the shorter intervals of approximation by P_n and S, which mask the weak 2-yr cyclic variation.

The existence of 2-yr cycle of W will be reexaminated by the partly different method.

Let $\Pi(s) = s_{12}s_{15}s_{17}s_{19}$ represent the Labrouste transform of W (Labrouste H., Labrouste Y. 1943, Djurović D., Stajić D. 1984). By this transform, whose selectivity function is presented in Fig. 4, the cyclic variations with periods $P_i > 42$ months were efficiently damped. Therefore, they are con-

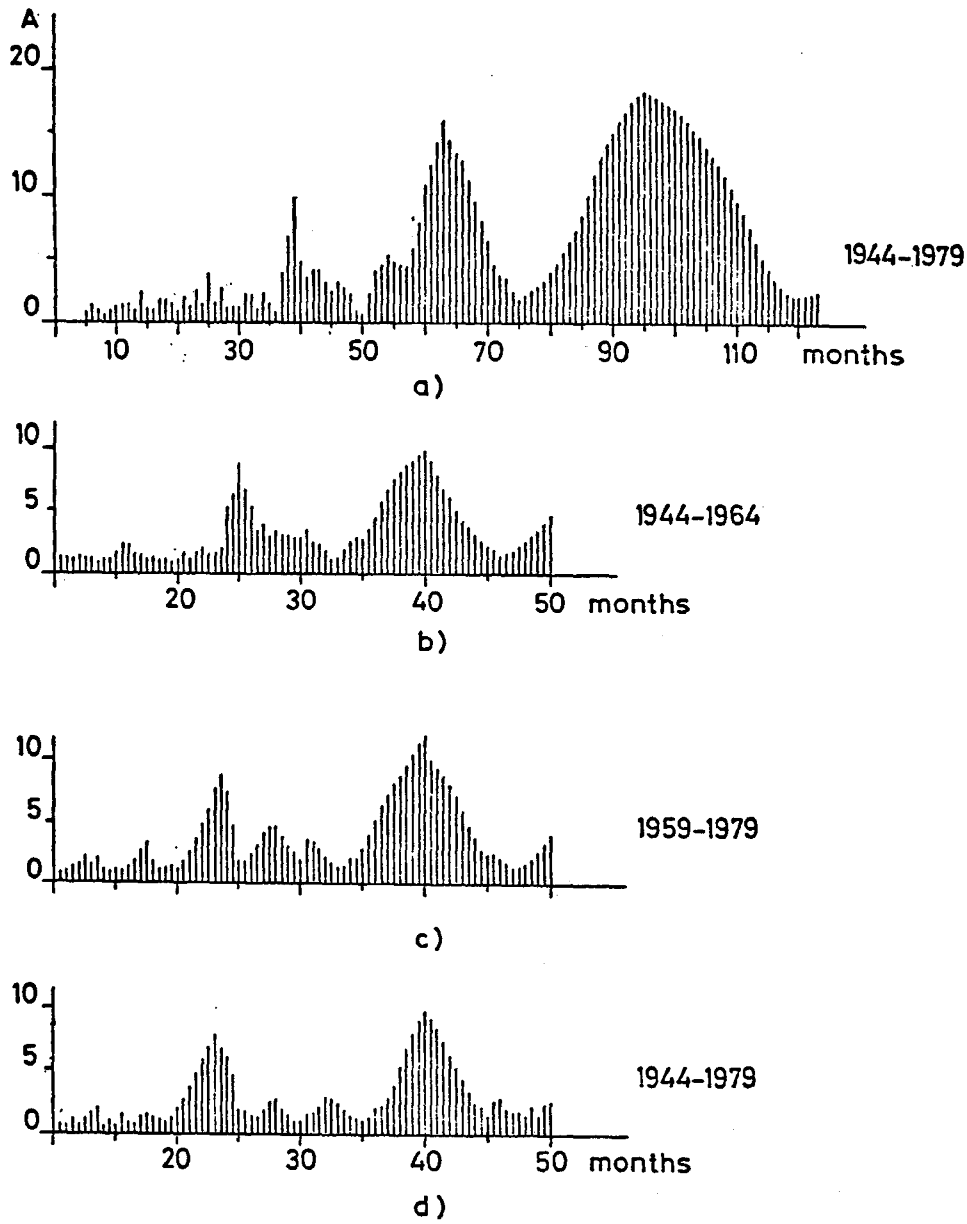

Fig. 3: The spectra of residuals ΔW (a, b, c) and ΔW'(d)

served in the residuals $\Delta W' = W - \Pi(s)$, if they exist, free of the main cycle and possible other cycles of larger periods.

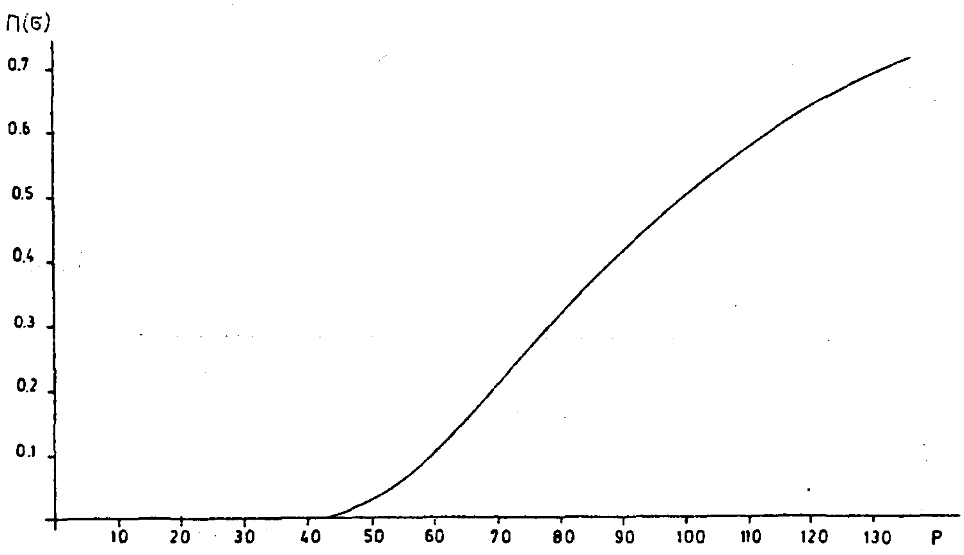

Fig. 4: The selectivity function of Labrouste transform $\Pi(s) = s_{12}s_{15}s_{17}s_{19}$.
The unit of P is 30 days.

In the spectrum of ΔW' (Fig. 3d) recomputed by the DFT method for the whole interval 1944—1979, 2-yr peak is well pronounced.

The numerical values of P, A, F of the cyclic terms of W are given in the Table II.

Because of the great inaccuracy of F (which depends on the amplitude), especially in the case of Aa, we do not reccomend their use without precaution. Despite this, we suppose that solar activity and geomagnetic field have the common cyclic variations of 2, 3.5 and 5.5 years. It is clear that the origin of these variations lies in the physical processes in the Sun.

The question which could be imposed after our present analysis of spectra of Aa and W and the previous one, of Ap, UT2 and W is: how to explain the contradictory conclusions of some authors, dealing with the short-period variations of solar activity and their geophysical consequences?

As we have seen in Fig. 2 and 3, as well as in Tables I and II, the amplitudes of 2, 3.5 and 5.5-yr cyclic variations are very small. Because of that, they are often masked by the noise fluctuations (as, for example, the biennal cycle in Fig. 3a). We suppose that here lies one cause of the mentioned confusion.

The above problem could be diminished by the comparative analysis of spectra computed over several independent subintervals of data. Only one spectrum is often insufficient to remark the weak, but permanent, details of the spectral picture.

4. CONCLUSIONS

Since common short-period cyclic variations have been identified in several independent series of observations (W, AM, UT2, Aa or Ap) we assume that these variations really exist. In favour of the above assumption is the physical dependence between solar activity and geomagnetic field and atmospheric density disturbances, proved earlier and confirmed by the recent space explorations.

TABLE I

The periods (P), the amplitudes (A) and phases (F) (with respect to the epoch $t_0 = 1950.0$) of cyclic variations of Aa.

	P	A	F
1868—1977	0.5 yr	2.2 ± 0.2	253° ± 7°
	1.9	1.3 0.2	159 15
	3.3	1.3 0.2	310 17
	5.4	1.8 0.2	262 9
	11.0	3.2 0.2	56 6

TABLE II

The periods (P), the amplitudes (A) and phases (F) (with respect to the epoch $t_0 = 1950.0$) of cyclic variations of W.

	P	A	F
1944—1978	2.0	9.1 ± 0.9	82° ± 17°
	3.3	10.6 1.2	64 15
	5.3	15.3 1.1	87 6
	10.8	66.4 1.0	152 1

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