VARIATIONS OF THE MAGNETIC FIELDS OF THE SUN AND THE EARTH IN 7–50 DAY PERIODS

V. P. BOBOVA and N. N. STEPANIAN
Crimean Astrophysical Observatory
334413 p/o Nauchny, Crimea, Ukraine

Abstract. The time variations of solar and terrestrial magnetic fields (background magnetic field, power of the active regions, AE and aa-indices) have been studied. The analysis of these data shows that multiplets of 27, 13.5, 9 and 7 day periods exist in the solar data as in the terrestrial data. The solar multiplets 13.5 and 9 days appear predominantly close to the equatorial zone of the Sun and can plausibly be explained by the presence of active longitudes. The similarity of the variations in period in solar and geophysical data provides evidence that the magnetosphere of the Earth is actually a continuation of the heliosphere. The variations of the terrestrial magnetic field are mainly determined by the solar background magnetic fields in middle heliographic latitudes.

1. Data and Method of Analysis

1.1. Solar Data

1.1.1. Synoptic Maps

The background magnetic fields were analyzed on the basis of Hα synoptic maps published in Solar Geophysical Data. The synoptic maps for 1969–1980 are represented by digits +1 and −1 as a function of the background magnetic field sign with a spatial resolution of 10°×10° for 10° latitude zones ($\varphi = \pm 50°$) and 36 longitude intervals (L=0°–360°).

1.1.2. Plages

Daily observations of area and intensity of plages in the interval 1969–1980 from Solar Geophysical Data were used to determine plage power, M. This is the sum of the product of the plage brightness times its area for each day the plage was on the disk. Thus, the plage power, M, is proportional to the full energy radiated by the plage during the time it was on the visible hemisphere. The spatial distribution of the background magnetic field polarities and the plage power in all 150 synoptic maps were written in the form of a two-dimensional array of 10×5400 terms. Each one of the 10 lines of the array corresponds to a 10-degree latitude zone. For plages, each term in this line corresponds to the power of the plages located in the central meridian zone (±5°). For the background fields, each term in a line labeled +1 or -1 corresponds to the polarity of the background magnetic field at that location. The time interval between two neighboring values is 0.75 days (10° of longitude).

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1.1.3. Relative Sunspots Numbers

Time sets are represented by daily average relative numbers of sunspots on the visible solar disk—R_z (Wolff numbers). These data are taken from Solar Geophysical Data for the corresponding years.

1.2. Geomagnetic data

1.2.1. AE index

This is the global index of the polar electrojet. It characterizes the change of H components of the magnetic fields for the auroral zone (Davis and Sugiura, 1966). Data for the interval 1966–1984 were obtained from NGDC (USA).

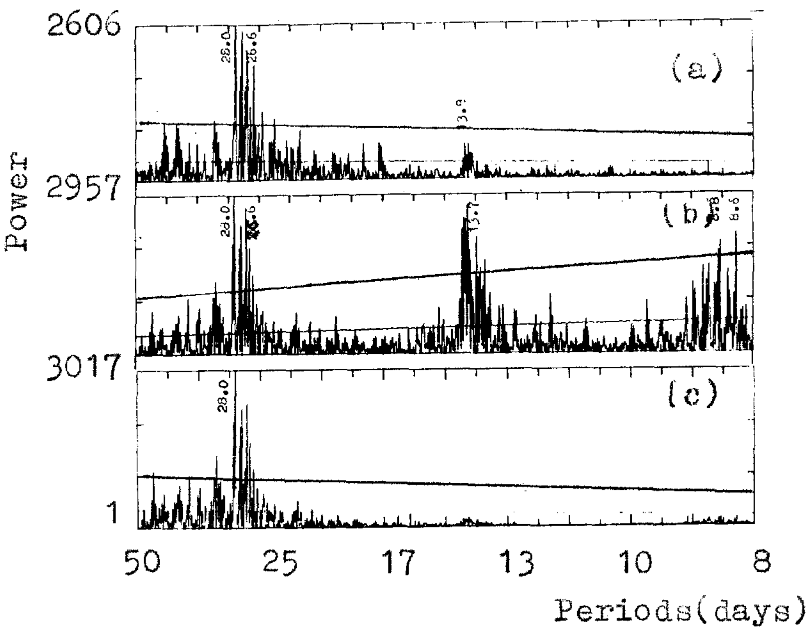

Fig. 1. The power spectra (1969-1980), (a) Wolff numbers, (b) plages ($\sum_\varphi$ M), (c) plages ($\sum_\varphi \sum_\theta$ M).

1.2.2. aa index

Data from two stations at antipodes (Greenwich and Melbourne) were used for constructing the aa index. The average k-indices were transformed into magnetic-field amplitude (Mayaud, 1972). The values of the aa-index were obtained from IDC B2 (Moscow) for 1868–1982.

For a study of the dynamical peculiarities of our time sets, a spectral-harmonic analysis (a superposed epoch with Fourier analysis) was used. Solar and geomagnetic data were analyzed using the same technique. This allows us to obtain power spectra, the most stable periods, and to estimate the full energy of the variations and study its distribution between separate harmonics during different time intervals. We analyzed the main range of 7–50 day periods with a step in frequency of 4.3×10^{-5} days.

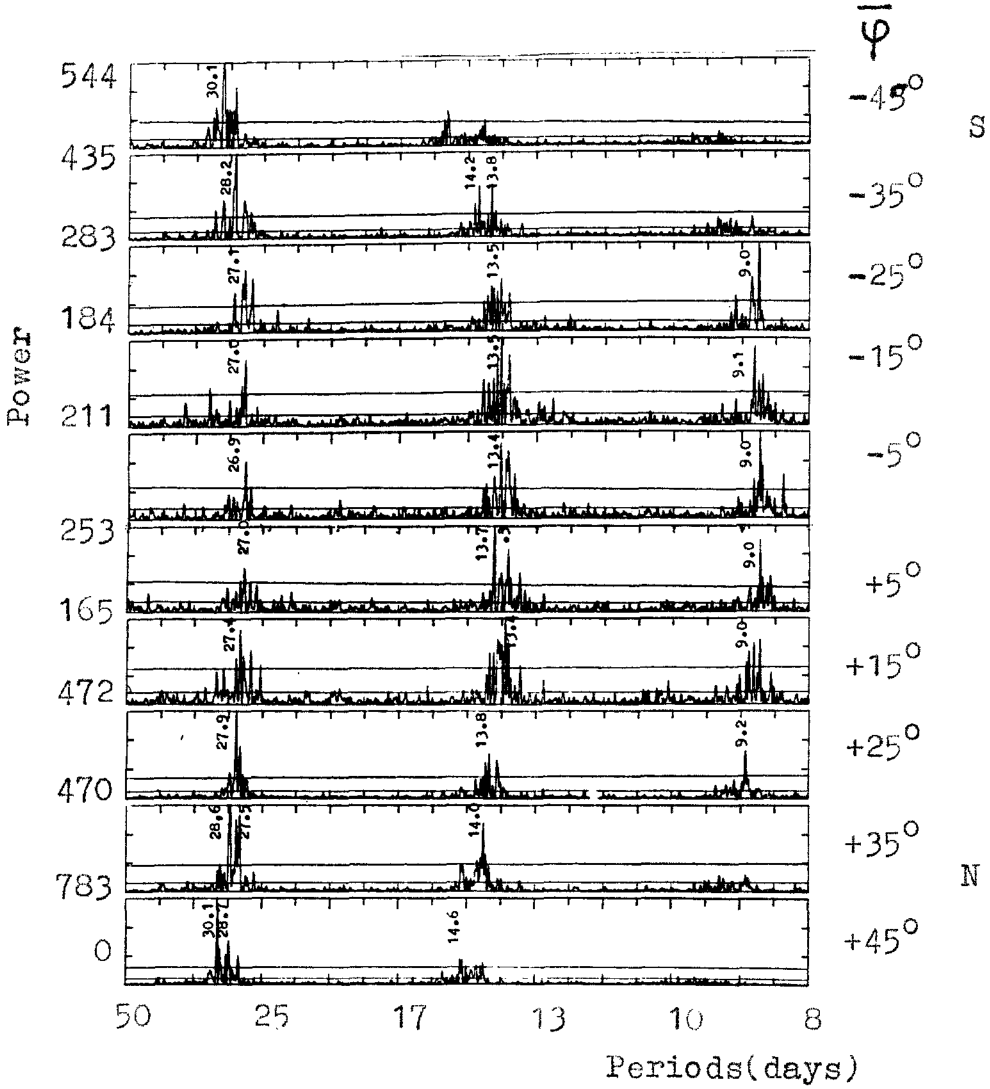

Fig. 2. Power spectra of background magnetic fields for different latitude intervals. Mean latitudes are shown at the right.

2. Results

The Wolff-number power spectrum and the plage power averaged over all latitudes are shown in Figures 1a and 1b respectively. As is seen in Figure 1a, the variations with periods 9 and 13 days are not appreciable. The reason is the following: Wolff numbers include sunspots over the whole disk. If we average the plage power over latitude and longitude, we have the result which is plotted in Figure 1c. Periods 9 and 13 days are absent in this spectrum.

The dependence of the power spectra on the spatial distribution of the solar background fields is shown in Figure 2. One can see that the spectra are different for various latitudes. The 27-day multiplet periods increase with latitude from 26 to 30 days. The structure of the 27-day period is explained by differential rotation. Periods of 9 and 13 days are observed in the equatorial zone, where the solar activity is the highest. The structure of all multiplets changes with time (Figure 3).

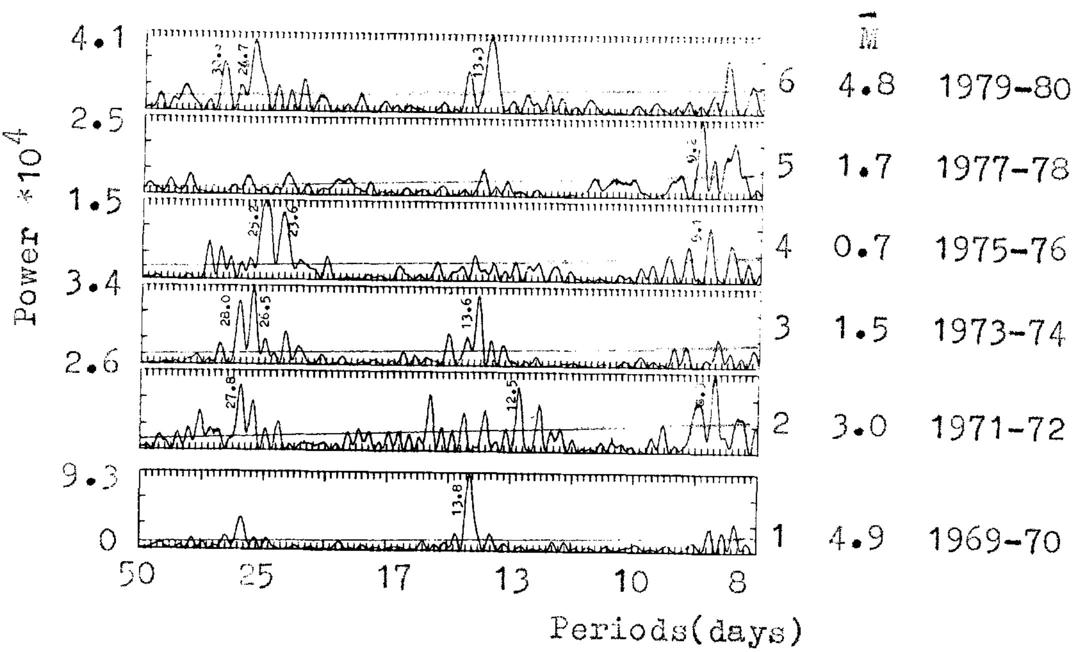

Fig. 3. The power spectra of plages ($\sum$ M) for 25 solar rotations. The mean value (M) is on the right.

Properties of the AE and aa-indices for the same dates were studied in the same way. The spectrum of variation of the geophysical data is similar to the solar spectrum (Figure 4).

The energetic characteristics of different multiplets—spectral power (SP) and the integral energy of the full spectrum (ISP) were studied. Variations of SP and ISP with time are not identical at different latitudes. Differences in SP take place for the most part at the middle latitudes. The smallest differences are observed in the central zone. The largest amplitude of 27-day multiplets of the background field are seen in the middle latitudes where the level of solar activity is low. In the central zone, where the level of activity is high, the spectrum of the background field is closer to the plage spectrum. The power of the different multiplets is almost equal (SP_{27}:SP_{13}:SP_9=1:1:1).

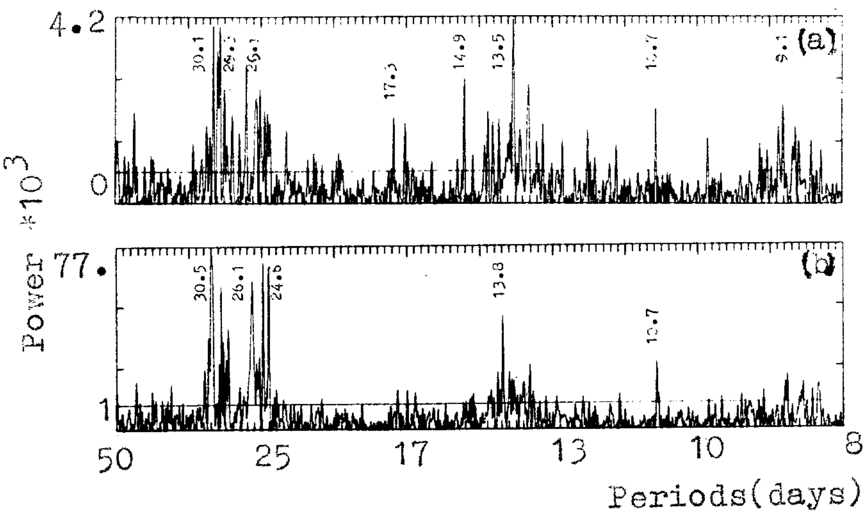

Fig. 4. The power spectra of the geomagnetic index for the interval 1969–80. (a) aa index, (b) AE index.

The ratios of the spectral powers of these multiplets for geophysical data are the same as for the solar background field in middle latitudes (SP_{27}:SP_{13}:SP_9=3:2:1).

Analysis of these results shows that the terrestrial magnetic field variations are determined by the solar background magnetic field in middle latitudes. This conclusion is confirmed by the connections found between ISP(aa) and solar activity for growing and decaying stages of the 11 year cycle (Figure 5).

3. Conclusions

We make the following conclusions:

1) The spectra of solar and geomagnetic data in the range of 7–50 day periods are characterized by a number of multiplets near 27, 13.5, 9, and

7 days. Their structure and properties depend on time, solar latitude and longitude.

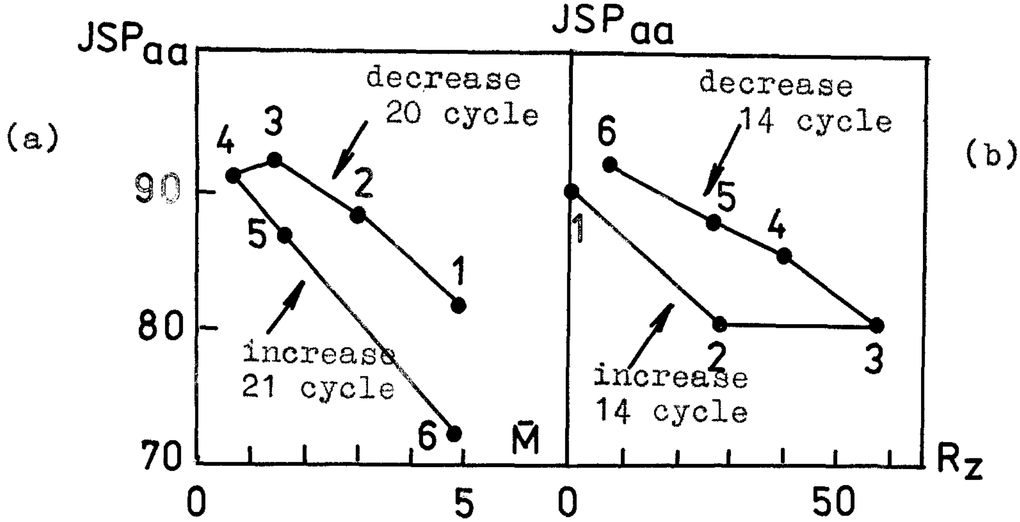

Fig. 5. The change of ISC_{aa} resulting from (a) plage activity, and (b) Wolff number for cycle 14.

2) The 27-day multiplets are caused by solar background magnetic field structures and their differential rotation.

3) The value of ISP for the background fields increases with increasing latitude.

4) The 13-, 9-, and 7-day periods are caused by the spatial distribution of solar activity.

5) Variations of the geomagnetic field are caused mainly by the solar background fields in middle latitudes.

6) An increase of solar activity causes a decrease of the integrated spectral energy, ISP, and a decrease in the stability of the multiplet structure.

References

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