"Physics of Auroral Phenomena", Proc. XXIII Annual Seminar, Apatity, pp.11-14, 2000

Polar
Geophysical
Institute

HELIOSPHERIC PLASMA AND MAGNETIC FIELD DYNAMICS DURING THE RISING PART OF THE 23-rd SOLAR CYCLE: COMPARISON WITH PREVIOUS CYCLES

A.V. Dmitriev; A.V. Suvorova, I.S. Veselovsky (*D.V. Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia)*

Abstract. Different averages (one and thirteen solar rotations) of the solar wind and interplanetary magnetic field parameters are calculated using the data obtained at the Earth's orbit for the current solar cycle and the three previous ones. The time-epoch analysis and hysteresis curves of the heliospheric and geomagnetic parameters show some general and specific properties of the cycles. The similarity between the rising phases of the 23-d and the 20-th solar cycles presents additional grounds for expectations of the lower maximum of the current solar cycle and the geomagnetic activity in the present solar cycle as compared with the 21-st and the 22-nd solar cycles.

Introduction

Cyclic variations of the heliospheric plasma and magnetic field parameters are produced by the solar activity changes [*Veselovsky et al.*, 1998; 1999]. The most often used indices of the solar activity are related to the sunspot numbers [*Vitinsky et al.*, 1986]. It is known that the average solar wind velocity at the Earth's orbit reaches the maximum value during the declining phase of the solar activity. The strongest average interplanetary magnetic field (IMF) strength is observed just after the solar maxima. The average solar wind density is enhanced during rising and declining phase of the solar cycles as measured by sunspots. Because of this, the geomagnetic activity is maximal near the solar activity maxima and during the declining sunspot activity phase.

On the other hand, the strong magnetic storms occur sometimes near the minimum of the solar cycle. This may be explained by the large dispersion of the heliospheric conditions that directly influence the geomagnetic activity. The purpose of this paper is to compare the dynamics of the heliospheric parameters at the rising phase of the current 23-rd solar cycle with the previous three solar cycles based on direct spacecraft measurements. An attempt to estimate the possible geomagnetic activity in the maximum and declining phase of the 23-rd solar cycle is undertaken.

Data analysis

Hourly averaged solar wind and interplanetary magnetic field parameters at the Earth's orbit are used from the data base OMNIWeb http://nssdc.gsfc.nasa.gov/omniweb/form/omniweb_retriever.html (1964-1996), SOHO (http://umtof.umd.edu/pm/crn/crn_data.html from 1997 to 2000) and ACE (ftp://sec.noaa.gov/pub/lists/ace2/ from 1998 to the March 2000) together with daily Wolf number (ftp://ftp.ngdc.noaa.gov /STP/SOLAR_DATA/ SUNSPOT_NUMBERS/) and hourly Dst-index of the geomagnetic activity (http://swdcdb.kugi.kyoto-u.ac.jp/ dstdir/).

Logarithms of all parameters were calculated and than averaged over time periods one and thirteen solar rotations. The results are presented in Figures 1-5 respectively for Wolf number *W*, IMF strength *B*, solar wind density *n*, velocity *V* and the maximal *Dst*-variation for the given month. We have also calculated the solar wind energy flux density $S_k=m_p*n*V^2$ (Fig. 6) and the parameter $BV=B*V$ related to the interplanetary induction electric field (Fig. 7).

The plots in Fig. 1 and in the top panels in Fig. 2-7 are constructed in the way which is the most comfortable for epoch analysis and comparison of the cycles. For this purpose, each cycle has its own time scale so that the minima of the different solar cycles are superimposed. The gray-scale coding refers to the cycles (corresponding to the axis color): the hard solid line corresponds to the 20-th solar cycle, the gray thin line - to the 21-st, the dashed line - to the 22-nd, and the hard gray line - to the current 23-d solar cycle.

The superimposed plots have their own and common features allowing one to investigate the dynamics. It is seen that regular and irregular variations are comparable and attain tens per cent for the averages and their deviations during the cycles. The comparison shows, that the important heliospheric quantities, that define the state of the solar-terrestrial interaction, during the rising phase of the 23-d solar cycle in general better follow the averages and deviations of the 20-th solar cycle, and not the 21-st or 22-nd solar cycles. It is especially true for the solar wind energy flux density S_k and the parameter *BV*, as well as for sunspot numbers.

The same tendency - a good correspondence between the rising phase of the 23-d and the 20-th solar cycle is demonstrated by the heliospheric "hysteresis" diagrams (bottom panels of Fig. 2-7). The gray scale codes is the same as in top panels. These diagrams clearly show the non-uniqueness of the yearly averaged heliospheric and geomagnetic parameters' dependencies on the Wolf numbers. The parameters attain different values for the same Wolf numbers at the rising part and at the declining part of the given solar cycle and in the minima and maxima of different solar cycles. The common tendency clearly seen in the "hysteresis" diagrams is that the heliospheric parameters have higher values in the declining phase than in the rising phase of the solar cycle.

Discussion

Solar cycles represent complicated nonlinear dynamical phenomena. Their primary physical nature and drivers are still elusive in spite of the large amount of secondary observational manifestations on the Sun, in the heliosphere and in the solar-planetary relations. The non-linear character of the solar cycles is seen, first of all, in the shorter and steeper rising parts as compared with the declining parts of the same cycle. Moreover, the steeper is the rising part, the shorter and more powerful the cycle will be, as a rule. This last property seems to be useful in attempts of a rough estimation of an expected power of the current solar cycle judged by the rising part only. Based on this predictor, one can expect that the 23-rd solar cycle will be similar to the 20-th solar cycle and not of a such big power as the 21-st and the 22-nd solar cycles.

The observed hysteresis behavior of the heliospheric parameters depending on the Wolf number is connected to the phase shifts between these characteristics. The maximum values of several heliospheric parameters are attained not at the sunspot maxima, but later in the declining phase. Strong fluctuations of the solar activity with the time scale of the order of the characteristic lifetime of the largest active regions prevent the precise determination of the times of the minima and maxima of the solar activity. The resulting precision is not better than several months.

The comparison of the averaged heliospheric condition and geomagnetic activity in the rising phase of the current and the 20-th solar cycles has shown some difference between two of these cycles. The main feature is the absence of a very strong magnetic storm like the one in April of 1967. Nevertheless, a relatively large number of the strong magnetic storms in the beginning of the current cycle testifies of the similarity with the 20-th solar cycle. In this case we can assume it is more probable that the maximum of the current solar cycle will not be accompanied by very strong magnetic storms contrary to the maximum of the 21-st solar cycle

Conclusions

The current solar cycle develops in a way, which is similar to the 20-th solar cycle. This lends some additional grounds for expectations, that the 23-rd solar cycle will be lower then two previous cycles in the solar, heliospheric and geomagnetic manifestations.

Wolf numbers are not sufficient for the one-valued ordering of the heliospheric conditions at the Earth's orbit and corresponding solar-planetary relations. It is because of the "hysteresis" between solar activity indices and heliospheric parameters.

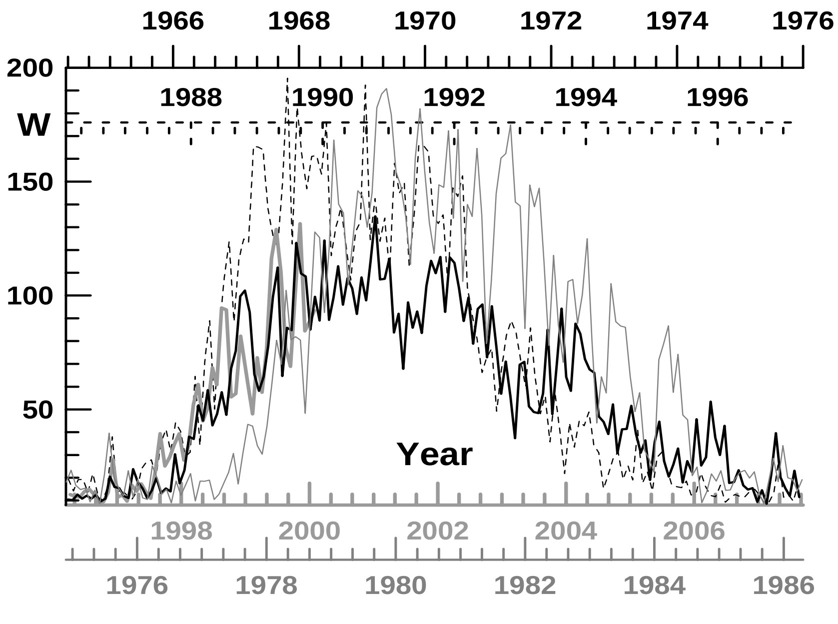

Fig. 1. Variations of the monthly averaged sunspot number *W*. The gray-scale coding refers to the cycles: the 20-th solar cycle - the hard solid line, the 21-st - the gray thin line, the 22-nd - the dashed line, the current 23-rd - the hard gray line.

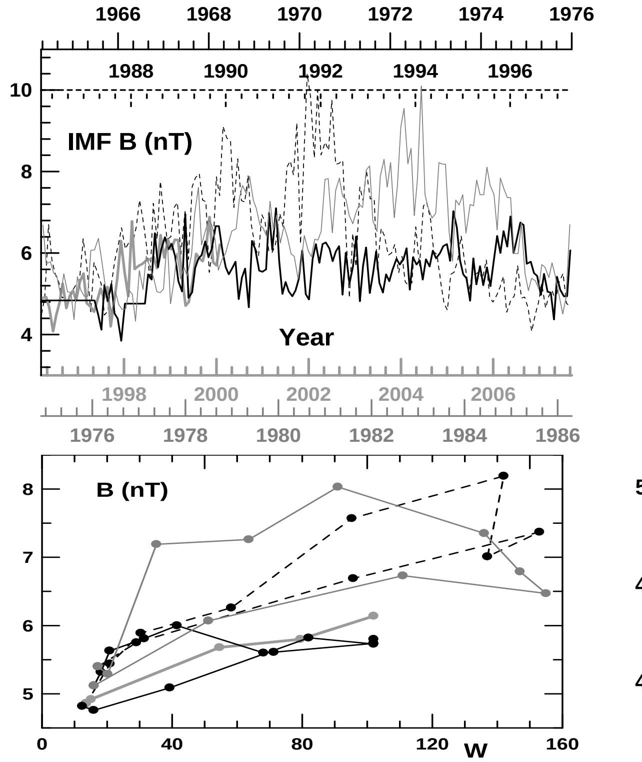

Fig. 2. Top panel - variations of the monthly averaged IMF strength *B*. Bottom panel - "hysteresis" diagram: yearly averaged IMF strength *B* versus Wolf number. Gray-scale code is the same as in Fig. 1.

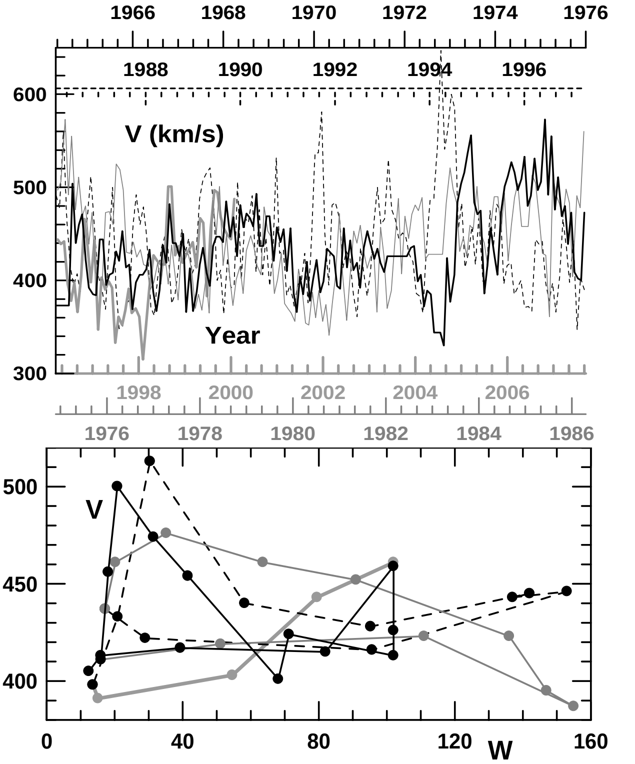

Fig. 4. Top panel - variations of the monthly averaged solar wind velocity *V*. Bottom panel - "hysteresis" diagram: yearly averaged *V* versus Wolf number. Gray-scale code is the same as in Fig. 1.

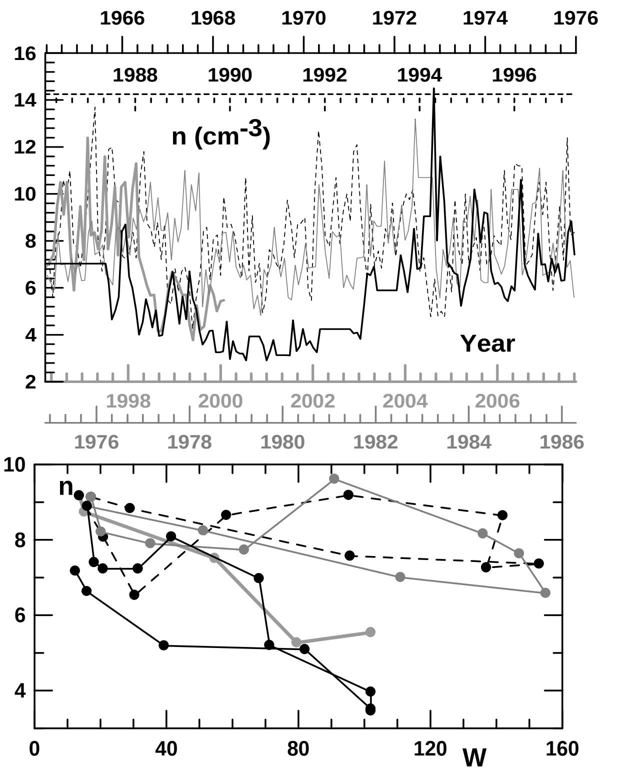

Fig. 3. Top panel - variations of the monthly averaged solar wind density *n*. Bottom panel - "hysteresis" diagram: yearly averaged *n* versus Wolf number. Gray-scale code is the same as in Fig. 1.

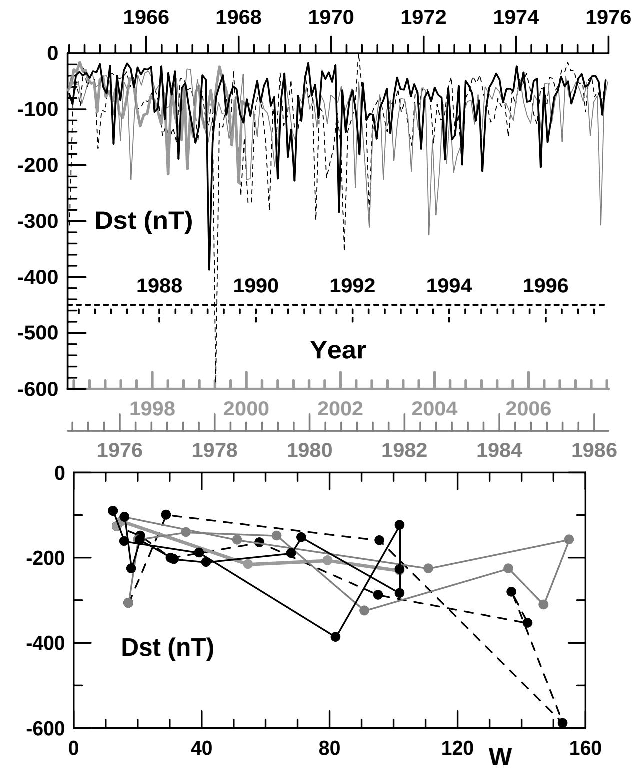

Fig. 5. Top panel - variations of the monthly maximum *Dst*-variation. Bottom panel - "hysteresis" diagram: yearly maximum *Dst*-variation versus Wolf number. Gray-scale code is the same as in Fig. 1.

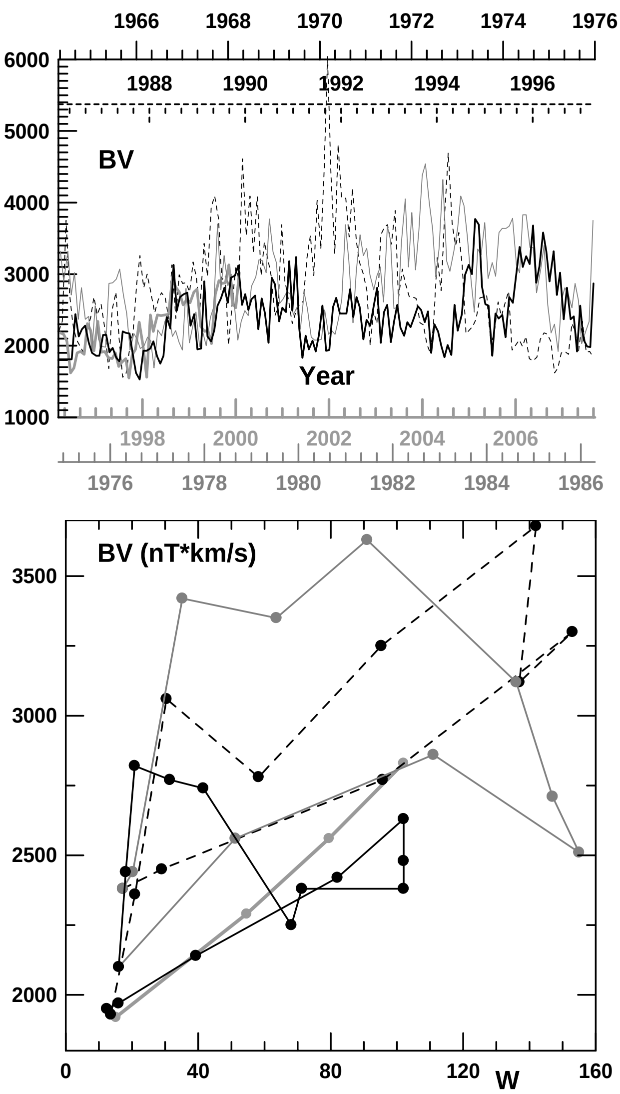

Fig. 6. The top panel - variations of the monthly averaged solar wind energy flux density S_k. The bottom panel - a "hysteresis" diagram: yearly averaged S_k versus Wolf number. Gray-scale code is the same as in Fig. 1.

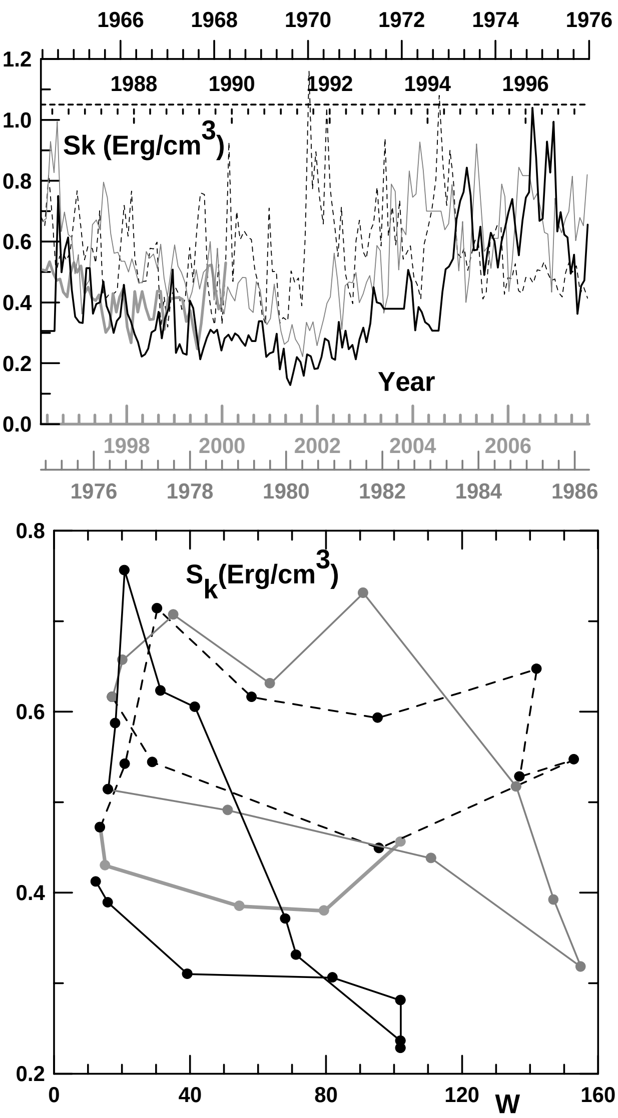

Fig. 7. The top panel - variations of the monthly averaged interplanetary induction electric field *BV* (nT*km/s). The bottom panel - "hysteresis" diagram: yearly averaged BV versus Wolf number. Gray-scale code is the same as in Fig. 1.

References

Veselovsky I.S., Dmitriev A.V., Suvorova A.V., Average parameters of the solar wind and interplanetary magnetic field at the Earth's orbit for the last three solar cycles, *Solar System Research*, *32*, N4, 310-315, 1998.

Veselovsky I.S., Dmitriev A.V., Panassenko O.A., Suvorova A.V., Solar cycles in the energy and mass outputs of the heliospheric plasma, *Astronomy Reports*, *43*, N7, 485-486, 1999.

Vitinsky Yu.I., Kopecky M., Kuklin G.V., Statistics of the sunsport activity, Moscow, Nauka, 1986 (in Russian).