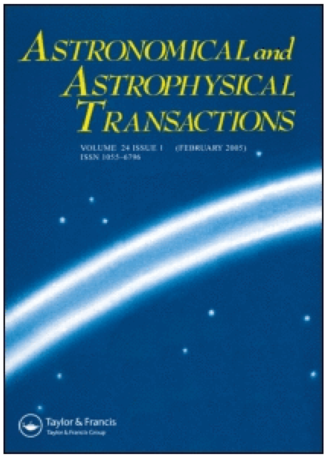

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High-resolution time changes in some indices and parameters of solar–terrestrial physics

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Comparison of the daily values of indices and parameters of solar–terrestrial physics in 2001 is made in order to allocate the most important values for future forecasts of geomagnetic activity. Changes in the indices and parameters describing all sequences of active processes from the surface of the Sun to the magnetosphere of the Earth were considered. The validity of application of the Wolf numbers as characteristics of solar activity due to sunspots is confirmed. The most geoeffective parameters depend on the arrival of the interplanetary shock from coronal mass ejection to the Earth's orbit and the presence of the southern component of the interplanetary magnetic field with intensity values less than -20 nT. If these parameters are known in real time, about 90% of magnetic storms with sudden commencement can be forecast within 8–10 h before the start of their negative influence on the Earth.

Keywords: Solar–terrestrial physics; Indices of activity

One of the main goals of solar–terrestrial physics is to study the influence of solar activity on the state of the Earth's magnetosphere. At present the level of solar activity is characterized by a series of known indices and parameters describing the different active structures and radiation fluxes from the Sun [1] at various wavelength intervals. The change in time of all active processes from the solar surface to the Earth's magnetosphere has been analysed. Both the old traditional indices of sunspot formation and the modern indices, which take into account the magnetic fields, X-ray flux and properties of the solar wind structure, are used.

The aim of the study is to separate the most geoeffective indices and parameters of activity of the system, in order to use them to forecast magnetic storms. In our research the following data for 2001 are used: the lists of sunspot numbers W; the values of the sunspot areas expressed in microhemispheres; the values of the solar X-ray flux background levels for $\lambda = 1$–8 Å in watts per square metre (GOES satellite); the values of the 10.7 cm solar radio flux in 10^{-23} watts per square metre hertz (Ottawa); the values of the flare index; the list of interplanetary shocks (data from the SOHO, ACE and WIND satellites); the onset of magnetic storms with sudden commencement (SSCs); the values of the geomagnetic activity index $-D_{\rm st}$ in nanotesla; the values of the southern component $B_{\rm zs}$ of the interplanetary magnetic field (IMF) in nanotesla.

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It should be noted that data about sunspots, flares, geomagnetic activity, X-ray and radio fluxes are represented by the daily values, while the recordings of SSCs and shocks have accuracies of 5 min and 1 min respectively; B_{zs} has 16 s averages that allows us to trace high-resolution time changes in the indices. Information was obtained from Internet sites.

If one traces the evolution of the chronological introduction of the indices of solar activity, then certainly the leading role belongs to the Wolf numbers. There are 1749 values of sunspot numbers which represent the longest time row. In spite of the numerous critical remarks about this index, W has no physical content; it has remained a unique and homogeneous parameter of solar activity for many years. Many researchers believe that the areas of sunspots are a more proven characteristic of solar activity, as sunspots areas are concentrations of magnetic flux. The daily values of these areas have been known since 1874.

Nowadays the most usually employed and the most available indicator of solar activity is the flux of the radio emission from all surfaces of the solar disc at $\lambda = 10.7$ cm. A linear relation between the radio flux at 10.7 cm and the full magnetic flux from active regions was found using numerous statistical data. Regular observations of radio fluxes have been carried out since 1947.

The Wolf numbers and the areas of spots characterize, to a greater degree, the static and potential activity of the Sun. In 1952, Kleczek was the first to introduce the flare index $Q = it$ to quantify the daily flare activity. He assumed that this relationship estimates roughly the total energy emitted by the flares. In this relation, i represents the intensity scale of importance and t is the duration of the flare (in minutes).

In order to characterize the activity in the region of soft X-ray emission from 1 to 8 Å an X-ray index is used. The daily values of the index are equal to the minimum of an average of the three 8 h intervals of flux of X-ray background levels. Regular recording of the X-ray flux began in 1974.

Such explosive processes on the Sun as flares and sudden disappearances of filaments are often accompanied by the occurrence of coronal mass ejections. The magnetic clouds of the plasma and particles move with a high speed and generate an interplanetary shock, which compresses the magnetosphere of the Earth and, as a result, the geomagnetic field sharply increases. The arrival of a shock on the Earth is evidenced by a sharp increase in the values of velocity, density and temperature in the solar wind. The regular recording of interplanetary shocks near the Earth began in 1996. All the shocks were divided into four different categories, which show the reality of their presence: from 1, indicating not sure, to 4, indicating very sure.

All the considered sequences of solar active processes quite often cause magnetic storms, which are, as a whole, a disturbance of the magnetosphere to an extreme extent. We divided the intensities of magnetic storms into four classes: class 1, weak; class 2, medium strength; class 3, strong; class 4, very strong. During 2001, 47 SSCs were recorded.

The geomagnetic index D_{st} monitors the worldwide magnetic storm level. It is constructed by averaging the horizontal component of the geomagnetic field from midlatitude and equatorial magnetograms all over the world. Negative D_{st} values indicate that a magnetic storm is in progress; the more negative D_{st}, the more intensive is the magnetic storm. The disturbance levels of magnetosphere are represented as follows: low, $D_{st} < -20$ nT; medium, $-20\,\text{nT} > D_{st} > -50$ nT; high, $-50\,\text{nT} > D_{st} > -100$ nT; extreme $-D_{st} < -100$ nT. An hourly D_{st} index has been derived since 1957.

The presence of the southern component B_{zs} of the IMF is also important. When the IMF turns towards the south in comparison with the Earth's magnetic field, the geomagnetic activity increases. As the B_{zs} values become more negative, the associated geomagnetic activity increases. The process of magnetic reconnection leads to an efficient transfer of energy from the solar wind to the magnetosphere. Regular recording of the IMF began in 1993 (IMP, WIND and ACE satellites).

The variations with time of all the enumerated indices and parameters of 2001 are considered (figures 1–3).

The behaviour of the variation in the sunspot number *W*, sunspot area *S* and radio flux all show good correlation with each other. Simultaneous increases in all the three indices are caused by the disc passage of activity sequences. The analogous behaviours of the indices indicate that each of these can be used to determine the sunspot activity. Thus, the practical use of *W* can be considered as a reliable, valid and adequate index, although it has no physical meaning. The synchronous variations in these indices were verified for the two previous cycles, too. On the other hand, a value of the radio flux at $\lambda = 10.7$ cm is a simpler and more readily available index.

Other indices and parameters are related to more dynamic processes and phenomena which have a typical time from some minutes up to some hours. For the flare index obtained from optical and X-ray observations, there is no synchronous variation with the indices of sunspot numbers (figures 1 and 2).

By definition, the geomagnetic index D_{st} describes the process of development of magnetic storms. It should be noted that the most powerful SSCs can be easily seen in the daily D_{st} variations (figure 2) but, in order to separate small and large SSCs, a high time resolution for D_{st} values is required.

A connection between the moment of shock front arrival at the orbit of the Earth and the beginning of a magnetic storm is clearly observed [2, 3]. The statistics of the 2001 data show that 41 shocks led to the occurrence of 39 SSCs. The interval of time between a shock arrival and the start of a magnetic storm is about 1 h. Only the occurrence of eight SSCs of weak and average intensity had other causes. So the recording of a shock near the Earth's orbit makes it possible to assume the occurrence of 83% of SSCs with a probability of 95%.

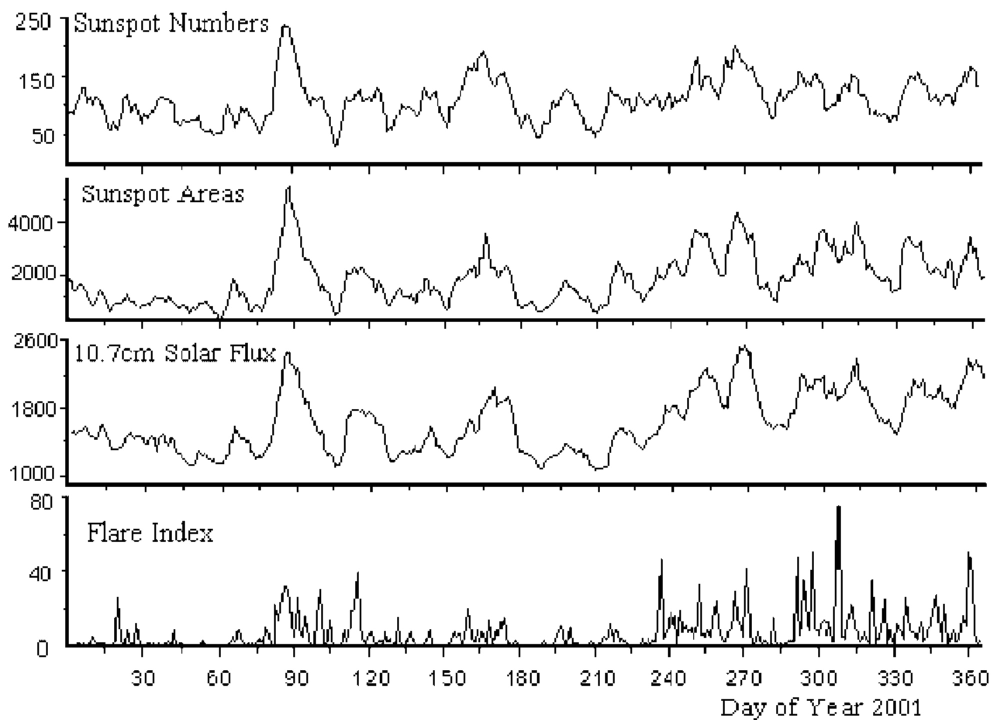

Figure 1. The daily changes of different solar activity indexes (see the text).

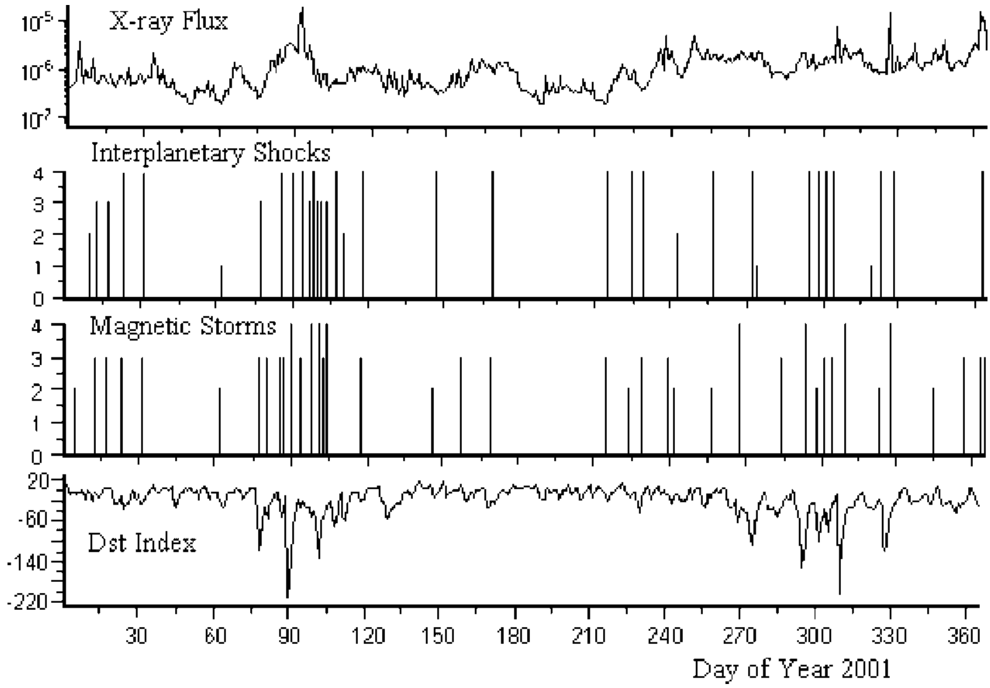

Figure 2. The daily changes of the X-ray flux, arrival times of interplanetary shocks, starts of magnetic storms, and Dst index in 2001.

One more geoeffective parameter is the value of the southern component B_{zs} of the IMF [4]. If the IMF has a large negative (forward to the south) component, the process of introduction of the IMF into the Earth's magnetic field is accelerated by magnetic reconnection, which leads to the accumulation of magnetic power in the magnetosphere. From figure 3, one can see the development of SSCs that took place within the time intervals where $B_{zs} < -20$ nT.

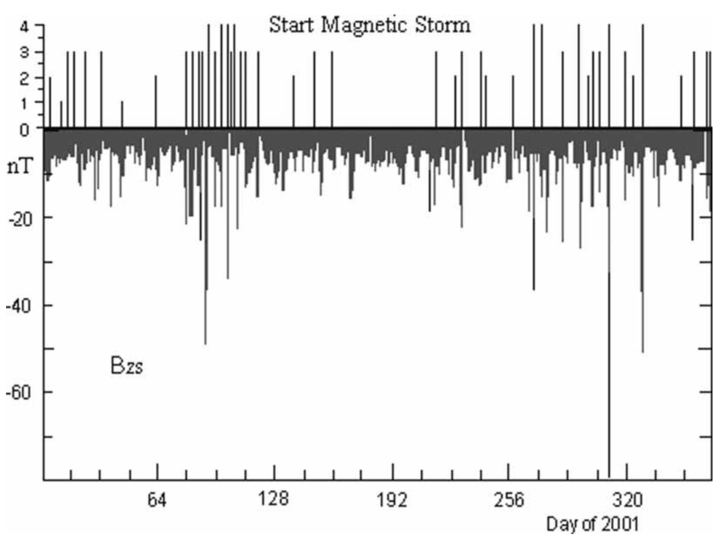

Figure 3. Comparison of beginning time of magnetic storms and BZS values (see the text).

From 14 SSCs which occurred in these periods, three were not connected with the arrival of a shock. Hence, not only powerful generating shocks but also interplanetary magnetic fields with $B_{zs} < -20$ nT lead to the occurrence of magnetic storms. As a result of the combined use of these two geoeffective parameters, the accuracy of forecasting magnetic storms is increasing.

Thus, in years of high solar activity, if real-time data from SOHO and ACE satellites (distance of 1.5×10^6 km from the orbit of the Earth) are used, about 90% of SSCs can be forecast within 8–10 h before they exert their influence. We take into consideration the fact that the negative influence of magnetic storms on the Earth usually begins within 7–9 h after their start.

References

[1] A.I. Galkin, M. Kopetckiy, G.V. Kuklin and E.A. Ponomarev, Issled. Geomagn., Aeronomii Fiz. Solntsa **83** 25 (1988).
[2] E. Echer, M.V. Alves and W.D. Gonzales, Solar Phys. **221** 361 (2004).
[3] G.S. Minasyants and T.M. Minasyants, Solnecno-zemnaya Fiz. **6** 187 (2005).
[4] D.F. Webb, *From Solar Min to Max: Half a Solar Cycle with SOHO*, *Proceedings of the SOHO 11 Symposium*, ESA SP 508, Davos, Switzerland, 11-15 March 2002 (European Space Agency Publishing Division, Noordwijk, 2002), p. 409.