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The variations of the solar magnetic field at the fast global reconfigurations periods

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Abstract. This paper presents the results of a comprehensive analysis of the dynamics of the sun's global magnetic structure, solar wind parameters, the interplanetary magnetic field and geomagnetic activity during fast global changes of magnetic fields on the Sun.

We have ascertained that the long-term variations of the large-scale and global solar magnetic fields have a nonmonotonic character (see Zherebtsov, Kovalenko & Molodykh (1997)). There exist three kinds of periods of fast global changes on the Sun in each cycle of solar activity, which are accompanied by anomalous manifestations in the heliosphere and in the Earth's atmosphere. The periods are characterized by increased flaring activity that reflects fast changes in magnetic structures. Changes in the global structures are quite well distinguished in particle flux density of a low speed solar wind (with velocities below 400 km/s), and in the B_z - component of the interplanetary magnetic field. On Fig. 1 are presented the data on long-term variations of the helio-geophysical parameters for the period from 1968 to 2001: solar activity, Wolf number (Rz), Ap-index of geomagnetic activity, solar wind particle flux, for a low speed solar wind (the velocity is less than 400 km/s), mean values of the modulus of the Bz -component of the interplanetary magnetic field, for a high speed solar wind (the velocity is larger than 500 km/s).

One period, during the rising phase of solar activity, corresponds to the start of the interaction of the 'old' cycle magnetic fields and emergent fields of the 'new' cycle. This interaction is accompanied by the destruction of a common current system, an enhancement of large-scale magnetic fields, fast changes in the global magnetic structure of the corona, and by a significant increase in inhomogeneity of the interplanetary magnetic field. Furthermore, 'favorable' conditions are created for an effective acceleration of solar cosmic rays. These periods are shown on fig.1 as gray dashed lines.

During the decreasing phase there occurs an opposite process - the interaction of the fields of the 'old' and 'new' cycles comes to an end, and a new common, global magnetic system is produced. This period is characterized by a simplification of the magnetic structure and by an attenuation of magnetic fields in the corona. These periods also are shown on fig.1 as gray dashed lines.

There also revealed the periods of fast global changes of the magnetic fields in the solar activity maximum phase. They correspond to interaction between the emerging large-scale magnetic fields and the existing fields in the solar atmosphere. The coronal mass ejections repeated periodically, are found, to take place during the periods of the fast global changes. The fast reconfiguration of the global magnetic field stimulates the fast changes of the smaller-scale fields. These periods are shown on fig.1 as gray arrows.

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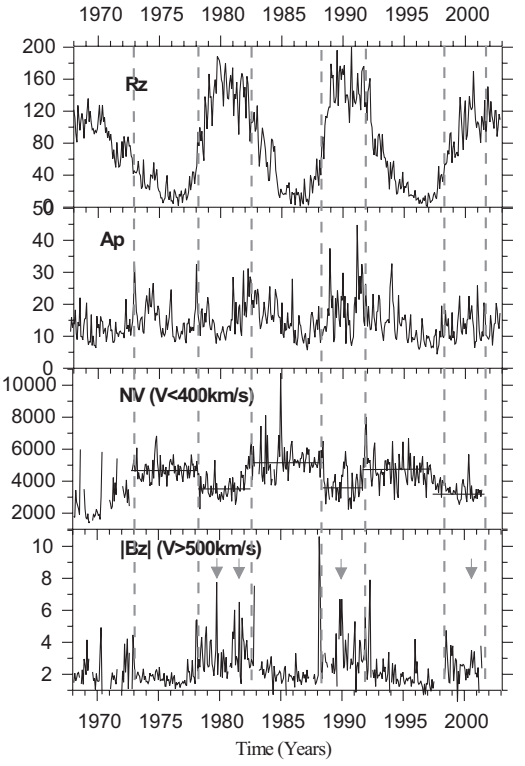

Figure 1. Long-term variations of the helio-geophysical parameters.

On the basis of analyzing the data, we may formulate a unifying concept. It is possible to figure out the scenario for fast variations and establish the key physical processes of interaction of magnetic fields in the Sun's atmosphere. As the magnetic field emerges from the convection zone, because of the high plasma conductivity in the solar atmosphere there is taking place a relatively slow mutual deformation of the emerging and pre-existing magnetic fields, i.e. a new current system is formed, which decays rapidly with the release of a significant amount of energy. This is due to the fact that, as the new magnetic flux emerges, an active interaction of magnetic fields sets in only when certain critical parameters are attained, i.e. the reconnection process sets in.

The process of a rapid change of strong magnetic fields is accompanied by a solar flare; the interaction of large-scale magnetic fields is accompanied by a mass ejection and by an acceleration of solar cosmic rays, while the global field develops a new structure, and triggers mass and magnetic field ejections. In accordance with this concept, a solar activity cycle either exhibits the whole scenario, or it shows only some parts of it. The main difference applies to the space-and-time scales of the interaction process, the magnitude of the magnetic field, and, accordingly, the distinctive features of the manifestation of the scenario in the solar atmosphere, heliosphere, and on the ground (Zherebtsov, Kovalenko & Molodykh (2004)). The main physical mechanism that leads to fast variations of the magnetic fields in the Sun's atmosphere is the reconnection process.

References

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