"Physics of Auroral Phenomena", Proc. XXXV Annual Seminar, Apatity, pp. 85 - 87, 2012

Polar Geophysical Institute

GEOMAGNETIC EFFICIENCY OF SOLAR EJECTION DEPENDED ON RELATIVE ORIENTATION OF SUN AND EARTH ROTATION AXES

N.A. Barkhatov[1], E.A. Revunova[1], A.E. Levitin[2]

[1]*Nizhny Novgorod State University of Architecture and Civil Engineering, Nizhniy Novgorod, Russia*
[2]*Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of Russian Academy oh Sciences, Moscow-Troitsk, Russia*

Abstract. Work is devoted studying of causes of seasonal variation of geomagnetic activity. Its axial hypothesis based on change Earth helioprojection on Solar disk during year, due to change of an inclination of Solar rotation axis to Sun-Earth line is confirmed. As a result of carried out research of latitude distribution of Solar sources geoeffective coronal mass ejections their displacement during the equinox periods to zones of active regions which are the basic source of Solar plasma ejections is established.

1. Introduction

Long study of geomagnetic activity showed presence of its semiannual variations, manifested as a maximum index of geomagnetic activity during the spring and autumn equinox [Chapman and Bartels, 1940]. To explain this variation developed several hypotheses. The main are axial hypothesis and equinox hypothesis. Axial hypothesis of semiannual variation of geomagnetic activity is associated with change Earth helioprojection on Solar disk during year [Cortie, 1912; Chapman and Bartels, 1940]. Due to change of inclination angle of Solar rotation axis to Sun-Earth line in direction to the Earth depending on terrestrial season on ~ 7°, in spring and autumn angular distance between Earth projection to Solar disk and Solar equator as much as possible. In these time-intervals Earth projection is located in zones of active Solar regions which are named in royal latitudes and settling down from 10 to 30 degrees northern and southern heliographic latitudes (fig. 1). During periods of winter and summer solstice Earth projection located around solar equator where active regions practically are absent. Thus, during equinox periods, when the Earth latitude of helioprojection is maximum, there is greatest probability to collision of Earth with Solar streams from active regions.

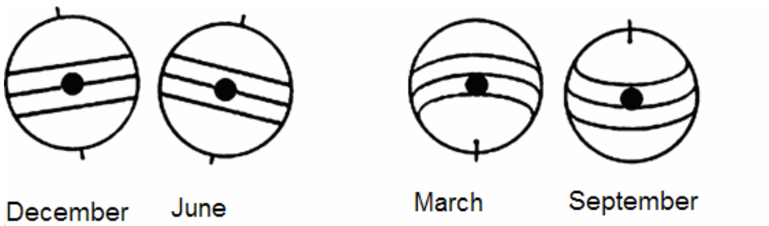

Fig.1. Change in Earth latitude helioprojection on Solar disk, depending on season.

Further studying of causes of seasonal variation of geomagnetic activity has led to occurrence of new hypothesis – equinox hypotheses in which inclination angle between geomagnetic dipole and Solar stream is considered. In an equinox hypothesis it is possible to allocate two basic models – Kelvin-Helmholtz instability (Boller-Stolov model) and Russell-McPherron effect [Boller and Stolov, 1970; Russell and McPherron, 1973].

The hypothesis about Kelvin-Helmholtz instability suggests that daily and annual variation of angle between Earth dipole and Solar wind lead to generation of instability on magnetosphere flanks. As was shown in work [Boller and Stolov, 1970] Kelvin-Helmholtz instability on magnetosphere flanks possesses semiannual variation, thus the instability maximum is necessary for equinox periods (when the terrestrial dipole is perpendicular to Solar stream), and a minimum – for solstice periods.

In framework of equinox theory one more explanation of seasonal variation of geomagnetic activity was suggest by Russell and McPherron in work [Russell and McPherron, 1973]. The interplanetary magnetic field (IMF) of Solar wind arises in Solar-equatorial coordinate system (GSEQ), whereas its influence on magnetosphere and geomagnetic activity depends already on sign and amplitude vertical Bz components of vector IMF in Solar-magnetospheric coordinate system (GSM). These coordinate systems have general axis X which specifies to the Sun, and axes Y and Z have different rotation round an axis X. Therefore Bx component of IMF will be identical in each system, and values component By and Bz will vary at transition from one coordinate system to another. Thus, the given hypothesis explains semiannual variation of geomagnetic activity as increase southern components of IMF in connection with its change in Solar-magnetospheric coordinate system in relation to Solar-equatorial system. This phenomenon has been named Russell- McPherron effect.

There is also representation about a direct connection between this activity and relative orientation of electric field vector **E** of Solar wind and geomagnetic moment vector **M** [Kuznetsova et al, 2006 and references in it]. However, as the electric field contains Bz component of IMF vector, it is possible that the relationship geomagnetic Kp index with the angle between **M** and **E** vectors is due simply dependent cosine of this angle of IMF Bz component in the Solar-magnetospheric coordinate system. In this connection, in work [Barkhatov et. al., 2008] the estimate Kp index and electric field and the Solar wind with projection of this field on the geomagnetic dipole has been executed. Here method for calculating Solar wind electric field, showing its greatest geoeffectivenes in form of correlation with an index of global geomagnetic activity Kp is developed.

Another cause of the greater number of magnetic storms and storms with strong intensity during spring and autumn equinoxes than in other months of the year may be seasonal dynamics of the coronal mass ejections (CME) parameters, type of magnetic clouds reach the Earth magnetosphere. Due to the fact that during the year changes in inclination of Solar rotation axis relative to Sun-Earth line, the interaction probability of the Earth with ejections from the royal zones increases during the equinoxes. Also in connection with passage of the Earth is closer to CME axis, which is observed strongest magnetic field is responsible for the intensity of the magnetic disturbances, and increases the probability of generating more intense geomagnetic storms.

2. Analysis of distribution of solar latitude sources geoeffective CME

In this work influence of inclination of Solar rotation axis to Sun-Earth line on seasonal variation of geomagnetic activity on catalogues materials of Solar flashes, CME (http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarflares.html; daw.gsfc.nasa.gov/CME_list/index.html) and by data about global geomagnetic activity on basis of Dst-index for full 23 Solar cycle (1996-2006) is investigate. Also distribution of latitudinal coordinates of Solar source of geoeffective CME registered in specified time interval is executed. The resulting distribution has two symmetric maximum in zones of royal latitudes ± $10\text{-}30^0$ (fig. 2), that indicating preferential location of Solar sources of geoeffective ejections in this range.

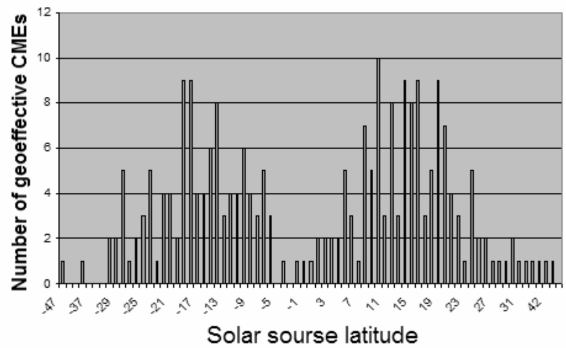

Fig.2. Latitude distribution of geoeffective CME Solar sources for Solar cycle 23.

As noted in the Introduction, change of Solar rotation axis angle leads to change of latitude Earth helioprojection. During equinox it gets in the royal latitudes in northern (the autumnal equinox), or in southern hemisphere (spring equinox). It can lead to increase in magnetic storms number in the given intervals. Division of analyzed data on solstice seasons (November-December-January and May-June-July) and equinoxes (February-March-April and August-September-October) showed presence of displacement of maximum in distribution of geoeffective CME latitude during the equinox periods (fig. 3). During periods of solstice Earth helioprojection latitude gets to area of Solar equator. Thereof CME from northern and southern hemispheres of the Sun are registered on the Earth in equal quantity (fig. 3). This regularity in analyzed 23 solar activity cycles is observed only for the period of a winter solstice (November-December-January). During summer solstice shift of latitudes in Sun northern hemisphere is observed.

To study characteristics of shift of geoeffective CME Solar source latitude during summer solstice analyzed data were divided in three parts: the rising phase of the cycle 1996-1998, maximum phase 1999-2002 and declining phase 2003-2006 (Fig. 4). The resulting distribution of Solar source latitude revealed that this shift occurs at maximum phase and declining phase of Solar activity, i.e. during periods of high solar activity. Consequently, such shift may be associated with complex distribution of Solar sources in these intervals.

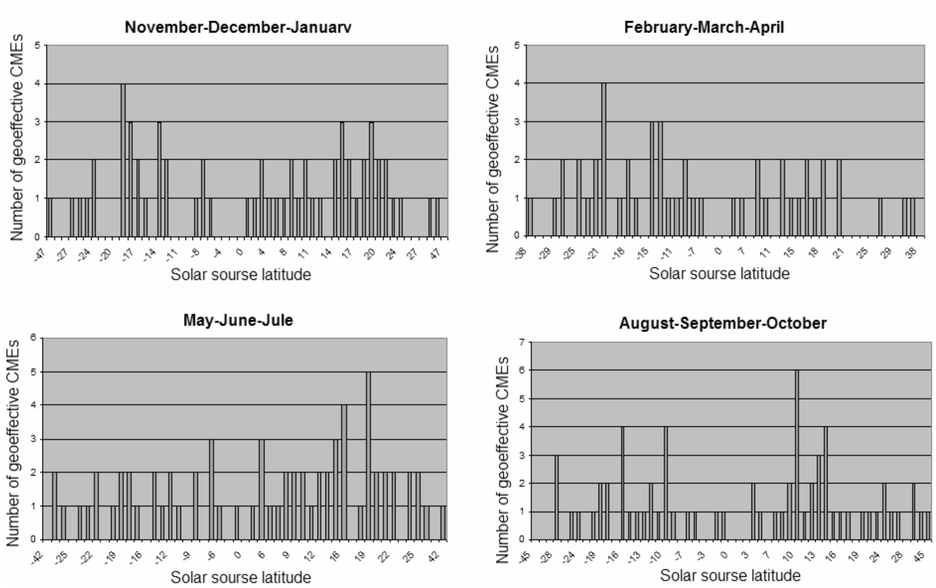

Fig.3. Latitude distribution of geoeffective CME Solar sources on seasons.

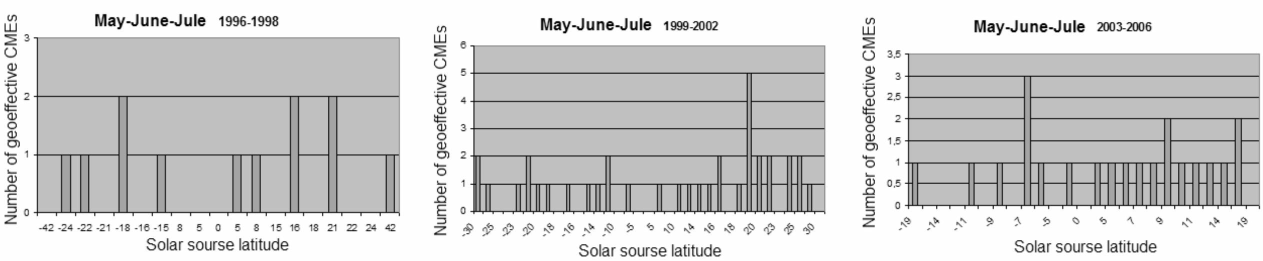

Fig.4. Latitude distribution of sources geoeffective CME in summer solstice by phase cycle: rising 1996-1998., maximum 1999-2002 and declining 2002-2006.

3. Conclusions

Research of latitude distribution of Solar sources of geoeffective CME for studying of influence of Solar rotation axis inclination on seasonal variation of geomagnetic activity is carried out. It is established, that during periods of autumn and spring equinoxes Solar sources of such streams mainly settle down above/below Solar equator (in zones of royal latitudes), while during the periods of solstice of coordinate have approximately symmetric distribution concerning equator (fig. 3). This effect is more pronounced in years of low Solar activity. Consequently, growth of geomagnetic disturbances during equinox is associated with increased in probability of magnetosphere meeting with plasma stream in these intervals. It occurs owing to change of Solar rotation axis inclination to Sun-Earth line and increasing latitude of Earth helioprojections on the Solar disk. At these moments, the Earth is projected to areas of active Solar areas, ranging between 10 and 30 degrees of northern and southern heliographic latitudes.

Acknowledgements. This work was supported by RFBR grant 12-05-00425 and by the project "Development of modern methods of forecasting the state of the magnetosphere-ionosphere in order to ensure successful communication by finding the fundamental regularities of solar activity" of Ministry of Education and Science.

References

Barkhatov N. A., Gromova L. I., Levitin A. E. and Revunov S. E. The relation between solar activity and orientation of the solar wind electric field relative to the Earth's magnetic moment Geomagnetism and Aeronomy, 2008. V. 48. N 6. P.713.

Chapman, S., and J. Bartels // Geomagnetism. Oxford University Press. New York. 1940. №. 11.

Cortie A.L. Sunspots and terrestrial magnetic phenomena, 1898–1911: the cause of the annual variation in magnetic disturbances. Monthly Notices of the Royal Astronomical Society. 1912. V.73. P.52.

Kuznetsova T.V., Laptukhov A.I., Kuznetsov V.D. Allowance for the geometry of solar wind interaction with the Earth's magnetic field in geoeffective parameters and in the prediction of geomagnetic activity // Solar System Research. 2006. V. 40. N 6. P.513.

Russell C.T., McPherron R.L. Semiannual variation of geomagnetic activity // J. Geophys. Res. 1973. V.78. P.24.