"Physics of Auroral Phenomena", Proc. XXXI Annual Seminar, Apatity, pp. 57- 60, 2008

Polar Geophysical Institute

LONG-TERM CHANGES OF GEOMAGNETIC FIELD ON IZMIRAN OBSERVATORY

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Abstract. Using of magnetometer data of Moscow observatory from 1946 to 2006 we have analyzed long-term geomagnetic variations, connected to the solar activity, against a background of secular changes of the Earth's Main Magnetic Field (EMMF). Taking into account of changes of geomagnetic activity inside solar cycles, reduces considerably a rate of secular changes of the EMMF.

1. Introduction

Geomagnetic activity created by magnetosphere and magnetosphere-ionosphere currents is defined, first of all, by solar corpuscular and solar wave radiations. A wave radiation determines a ionosphere conductivity, and corpuscular radiation – intensities of current systems and particle's precipitations, also causing a change of ionosphere conductivity. The dynamics of intensity of these radiations includes regular and accident components. Regular component is a time change of solar radiation during 11-years solar activity cycle, and steady dependence of geomagnetic activity on parameters of the solar wind and interplanetary magnetic field (IMF). Most great geomagnetic disturbances relate to casual component. They occur when following events take place: an occurrence of a solar coronal mass eruption (CME) in a concrete area of the Sun; impact of this CME on the magnetosphere; presence of a negative vertical component ($B_z < 0$) of IMF vector; passage of the Earth through the CME where such field contains. Due to this accident, the distribution of number of magnetic storms monthly during an year and the general number of storms year by year can vary accidentally, and it affects in the dynamics of annual values of geomagnetic field registered by magnetic observatories, and of geomagnetic activity indexes. Therefore definition of rate of secular changes of the EMMF based on observatories data is an incorrect problem. Taking into account of influence of geomagnetic activity due to magnetosphere current systems on secular changes is required.

The natural part of geomagnetic activity, connected to regular influence of solar activity on ionosphere conductivity and electric field, varies during solar cycles. These changes of a variable part of geomagnetic field are not taken into account by modern methods of calculation of models of internal magnetic field of the Earth, and lead to the overestimated values of time-rate-of-change of the EMMF year by year. About a role of solar activity at secular variations of the EMMF it is spoken, since first third of 19 century, but quantitative estimations till now are not submitted.

Presence of regular uniform observatories geomagnetic measurements for long time interval allows to use them for analysis of long-term geomagnetic variations which are usually attributed to secular variations of the EMMF. Such variations are found at the analysis of time changes of annual means of elements of geomagnetic field for network of magnetic observatories. The problem of decoding of the nature of these variations is solved many years, and the problem consists in that geomagnetic activity always gives its contribution to annual means of geomagnetic data which it is difficult to allocate at a quantitative level. Influence of geomagnetic activity on annual amplitudes of components of a geomagnetic field vector in observatories is shown, mainly, by that these annual values reveal quasi-periodic variations with characteristic time ~11 and 22 years of the solar activity. Such variations were noticed, since first third of 19 century, and since questions of exception of effects of solar activity from the observatories data were discussed routinely in scientific publications.

We show presence a similar cyclic variation in annual average values of elements of terrestrial magnetism based on the data of observatory IZMIRAN (Moscow) for the period of 60 years. Simultaneously, we show connection of long-term variations of monthly means of H-element of geomagnetic field during quiet geomagnetic days with parameter of solar activity F10.7. Such connection shows that one of physical causes of quasi-periodic geomagnetic field variations, with characteristic time of ~11 and 22 years, is a change of ionosphere currents intensity due to a change of ionosphere conductivity inside cycles of solar activity.

2. The method of data processing and results of research

Data of observatory Moscow for 1946-2006 have been used for examination a cyclic 11-years variation in annual averages of elements of geomagnetism. They are: horizontal H-, northern X-, east Y- and vertical Z-components of a vector of geomagnetic field, the module of vector T, declination D, and inclination I. Annual means of these magnitudes received for all days of year (with the index a), for international quiet (q), and disturbed (d) days were analyzed.

Separately, the analysis of monthly average values of horizontal H-component for q-days has been carried out. They

were compared to the time series of monthly means values of parameter of solar activity F10.7 which characterizes solar wave radiation with wave-length of 10.7 cm, and determines the dynamics of ionosphere conductivity during 11-years solar cycle.

To allocate of cyclic variations with the period ~ of 10-11 years from long-term changes of geomagnetic elements it was assumed that magnetic disturbances during magnetic storms, at their averaging for a long time interval, do not turn to a zero. As basic values at allocation of cyclic variations we accepted the annual averages of elements during minima of solar activity. As basic lines of these elements the sequence of data received by averaging of q-days data of each year is accepted.

Such technique of the data analysis differs from a standard technique which is used at studying secular geomagnetic variations when a sequence of annual average data is received from all days of year. Thus usually supposed, that all disturbances of geomagnetic field in the year (positive and negative) are averaged up to zero, and consequently it is possible do not use annual averaging for quiet days. But it is well-known, what even in quiet days the index Dst, describing a H-component of magnetic disturbances in low latitudes, shows negative values ~ (-10÷-20 нТл). As within minima of magnetic (solar) activity the geomagnetic field is the least disturbed, at analysis of cyclic variations of long-term changes of magnetic elements it is necessary to use as basic values within years of sunspot minima.

Figure 1 shows the following long-term variations of annual means of geomagnetic element H (a horizontal component of a vector of geomagnetic field) from observatory IZMIRAN (Moscow) for the period from 1946 to 2006 years: annual means of H for all days of year (H_a) – the solid line; for disturbed days (H_d) – the line with squares; for quiet days (H_q) – the line with asterisks. As in second half of the last century, years of sunspot minima alternated approximately in 10 years, in Figure 1 vertical dashed lines pass in years: 1945, 1955, …, 1995, 2005. One can see cyclic variations of magnetic element H at each of cycles of solar activity. The most high-amplitude variation is observed for H_d, the most low-amplitude cyclic variation is visible in H_q. Long-term number of H_a which is used at studying of a secular trend, contains a intermediate amplitude of a cyclic variation, between H_d and H_q. It can be seen from Figure 1 that values of H_q are the local minima within of solar activity minima. The smooth enveloping curve shown on Figure 1 should reflect more correctly secular variations of the EMMF since it is released, in the certain degree, from the cyclic variations created by external current sources.

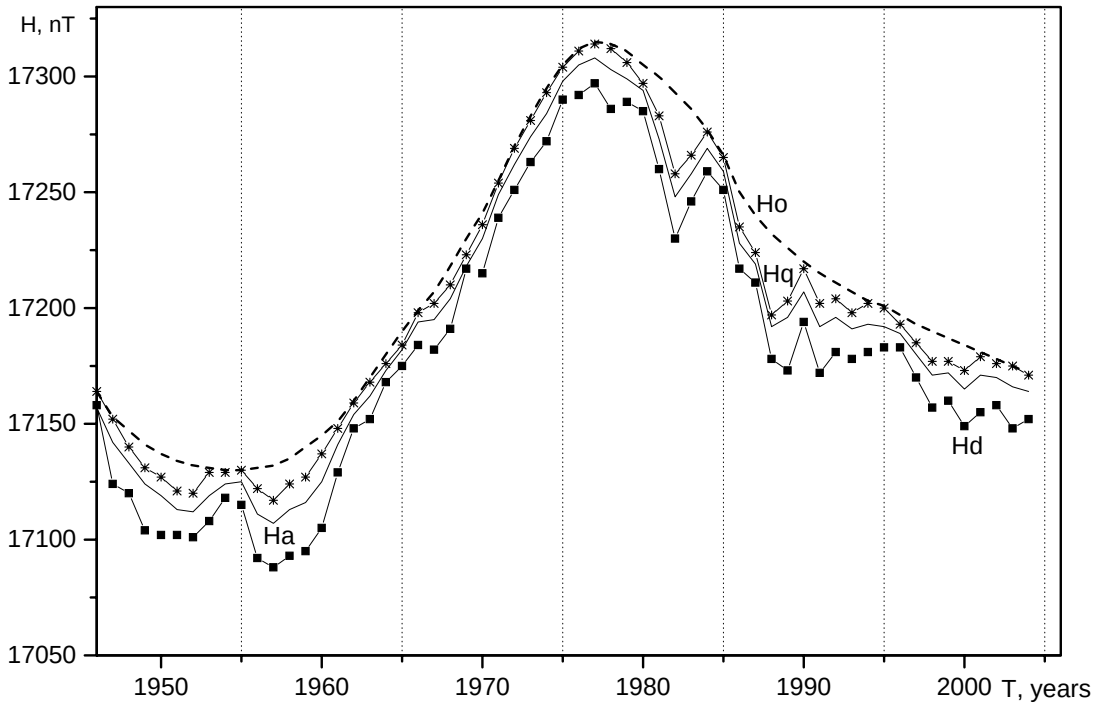

Fig. 1. Annual means of H-component from Moscow observatory for 1946-2006: H_a – the data for all days (solid line); H_d – for disturbed days (line with squares); H_q – for quiet days (line with asterisk); H_o- the smooth enveloping curve, connecting H_q-values during sunspot minima. The dashed vertical lines show years of sunspot minima.

Secular variations of element Z (vertical component) from observatory Moscow (annual means of Zq, Za, Zd) are closed to each other enough. The 10-years cyclic variation which through one cycle changes its values on opposite. That is, an element Z shows the full near 22-years cycle of solar activity.

All other elements of geomagnetic field of observatory Moscow in the time interval of 1946-2006 also have cyclic

variations with the period ~ 10 years. Thus, an element X practically does not differ from an element H, as for D ≈ (7÷9)° size X = H·cosD ≈ 0,985H. Secular changes and cyclic variations of a module of field T repeat variations of an element Z. Average value $T_m \approx 1{,}06Z_m$ for all a time interval ~ 60 years.

Secular changes of other three elements (D, I, Y) of geomagnetic field on observatory Moscow are similar each other, but character of these changes differs from described above. In the first decade they linearly grow, in the second decade this growth is considerably slowed down also a local maximum reached in 1966, in the third decade there is a slow recession up to a local minimum in 1976. The next three decades fast, almost rectilinear growth of elements, as in the first decade, is marked. Thus, elements D, I, Y cyclically vary in each decade.

Geomagnetic activity depends on a condition of current systems existing in the near-Earth environment. Intensity of a current in these systems is defined by a capacity of the generator of each system and its conductivity. One of the most important current part is the ionosphere which conductivity is determined by wave radiation of the Sun. Capacity of generators, basically, depends on a level of receipt of energy in the magnetosphere from the interplanetary environment. Dependence of an intensity of ionosphere current on solar wave and corpuscular (a solar wind) radiations leads to presence inside long-term variations of geomagnetic field elements variations with the periods about the cycle

of solar activity. For the proof of this fact it is possible to compare long-term variation of H-component on a concrete observatory (as it is the most sensitive to variations of an ionosphere current) to a variation of parameter of the solar activity F10.7 controlling a time course of ionosphere conductivity.

Figure 2 shows a long-term number of monthly means of H-element for quiet days of an year (monthly average values of H_q) in an observatory Moscow for the 60-years period (1946 - 2006) and a number of monthly means of parameter F10.7 for the same time.

Figure 3 shows also values H_q (t) and F10.7 (t) for interval of 84 months, since 01.01.1946. The coefficient of a linear correlation between H_q (t) and F10.7 (t) on this interval make 0.69, that shows a reality of connection of long-term variations of geomagnetic field, associated to solar activity, which carry to secular variations of the EMMF.

Variations of a solar influence on the Earth's environment determine the dynamics of ionospheric conductivity and of receipt of electromagnetic energy in the magnetosphere, that leads to change of large-scale current systems intensity and, consequently, change of a condition of a variable part of the magnetic field of the Earth. Geomagnetic activity varies as inside one year, and year by year in a cycle of solar activity.

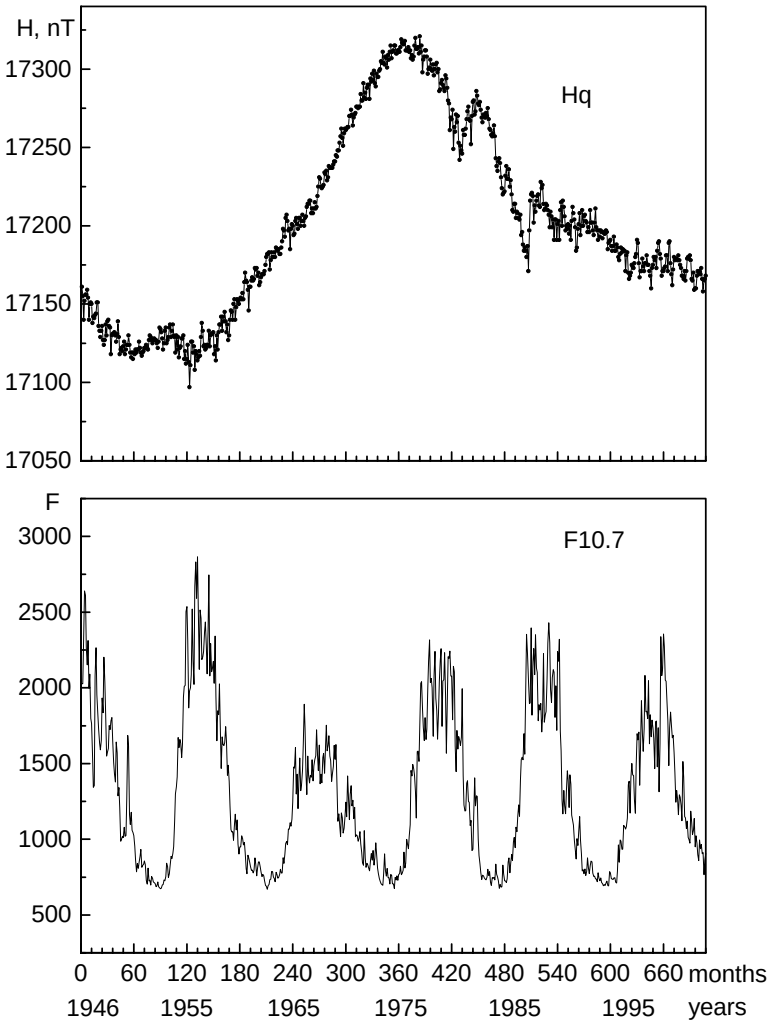

Fig. 2. Monthly means of H-component of geomagnetic field for q-days from Moscow observatory and the solar activity index F10.7 for 1946-2006.

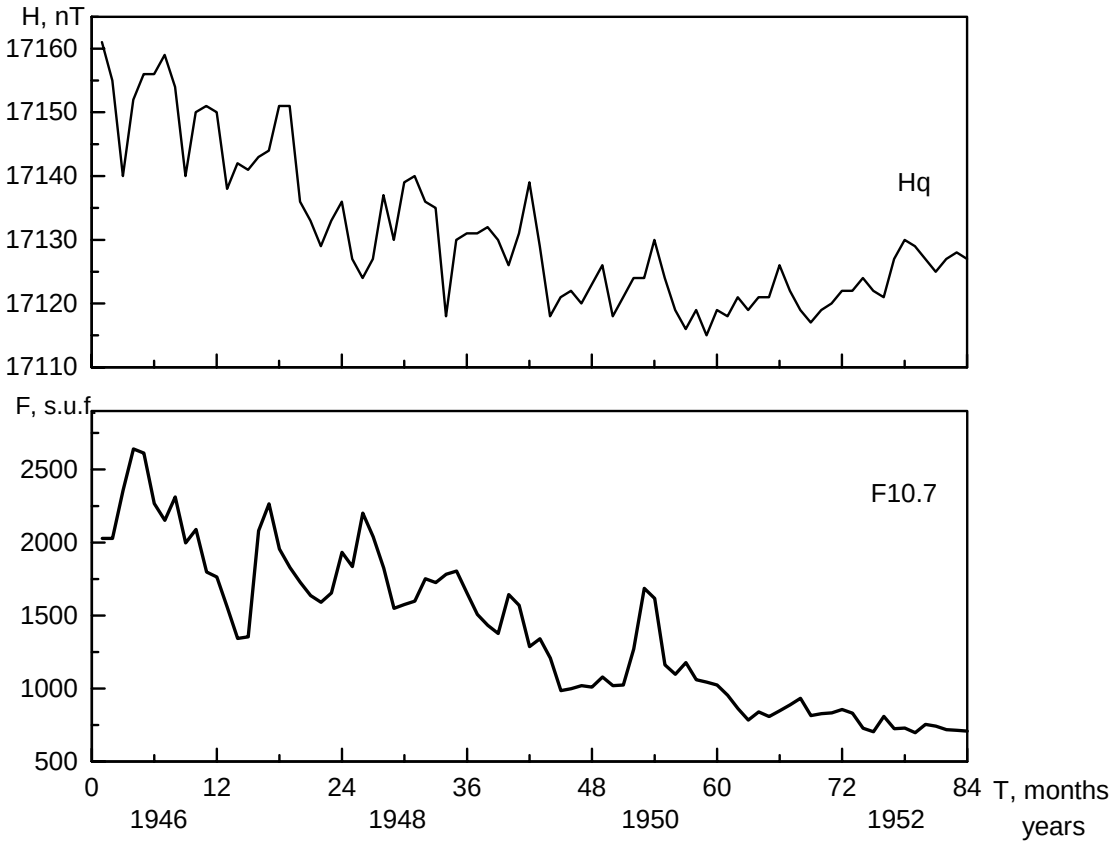

Fig. 3. The distributions of monthly means of $H_q(t)$ and F10.7(t) for the period of 1946-1952; the correlation coefficient R between 84 values of H_q and F10.7 is equal to 0,69.

3. Conclusions

Our results agree with conclusions of the researchers about presence of quasi-periodic variations in the long-term annual averages of geomagnetic field elements with the characteristic time equal to period of solar activity ~ of 11(22) years**.** Except for demonstration of similar variations in the geomagnetic data received in observatory IZMIRAN, we indicate that they are connected with the dynamics of magnetosphere-ionosphere current systems during of sunspot cycles. As the proof of presence of such relation, the correlation between monthly means of H-element and monthly values of solar activity parameter F10.7 inside these cycles serves. The physical reason of such relation is the dynamics of current systems intensities in the Earth's environment, generating a variable magnetic field. Separation of the contribution of external sources of a geomagnetic field in secular variations can considerably reduce the estimation of rate of change of the Main magnetic field of the Earth accepted today.

Acknowledgments. The research was supported by RFBR grants №№ 08-05-00896 and 07-05-13524**.**