The New Method of the Extraction of Seismic-tectonic Effects from Results of Geomagnetic Measurements of Low-orbit MAGSAT, CHAMP Satellites

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The activities in the field of differential magnetic calculations from satellites CHAMP and MAGSAT were continued. The goal of the present paper is the identification of spatial-temporal gradients of geomagnetic field for the Europe-African region. An apart from of refinement of magnetic anomaly field of sub-sinusoidal anomalies presumably connected to the magnetic non-uniformity of the seismic effects in rift zone was detected. The differential spatial-temporal calculations (DSTC) from geomagnetic satellite data is the alternative for direct horizontal gradient methods (DGM) of the extraction of geomagnetic variations from satellite differential measurements (SWARM satellite). The extraction of magnetic anomalies by two methods (DGM and DSTC) increases confidence to outcomes of the geophysical interpretation. The study, measured with the satellite differential magnetic data has allowed to create algorithm for extraction of anomalies connected with seismic-tectonic effects.

Introduction

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One from new methods of extraction of geomagnetic anomaly field connected with the seismic-tectonic effects from the noise of the geomagnetic field connected with the ionosphere-magnetosphere sources and internal tectonosphere sources of the Earth are the methods differential spatial-temporal calculations (DSTC). From the MAGSAT, CHAMP satellite measured geomagnetic field (F_s) data the main magnetic field (F_m) of Earth's core was previously eliminated. The residual geomagnetic field (F_r) is present in magnetic anomalies of tectonosphere origin (F_a) and variation of the ionosphere-magnetosphere variable field (F_v). The partial differential of a geomagnetic field per time from the schedules the vector components of the low-orbit satellite MAGSAT, CHAMP was calculated. The extraction of seismic-tectonic effects from the data of the partial differential of vector component geomagnetic field per time is made better, than from the residual geomagnetic field. For extraction from the MAGSAT, CHAMP low-orbit satellite geomagnetic data of the anomaly effects of the ionosphere-magnetosphere and the tectonosphere we shall consider the differential spatial-temporal calculation (DSTC) formulas, from which we leaned at computer calculations. For improving the situation with extraction of seismic-tectonic effect from the noise of the MAGSAT, CHAMP low-orbit satellite geomagnetic data, the algorithm of high-frequency filter of the Lagrange to values of a combinational partial differential of a geomagnetic field per time was applied.

DSTC Method of processing of the geomagnetic data of MAGSAT and CHAMP satellites

Differential spatial-temporal calculation (DSTC) analysis with the use of the partial differential per time is applied in the different values of speeds. The DSTC method essence consists of selection of virtual temporary measuring base (Δt):

$$\Delta t = \upsilon / \Delta L, \quad (1)$$

where υ – the speed of the satellite with the magnetometer, ΔL – the virtual spatial measuring base.

It is necessary, that during Δt one from increments F_a or F_v was less sensitivity of the magnetometer (ε). F_a and F_v - accordingly one from the component of magnetic anomaly field in driven coordinate system and geomagnetic variation. Then F_a or F_v will be absent on a differential curve. At $\Delta t << T$, F_a and F_v will be less sensitivity of the magnetometer (ε), that is in the basis of DSTC filtration of geomagnetic field lies. In the future it will have a capability to compare outcomes DSTC method to the data of the towed installation with diverse in space by three magnetometers from SWARM satellite geomagnetic survey measurements (fig.1)[1].

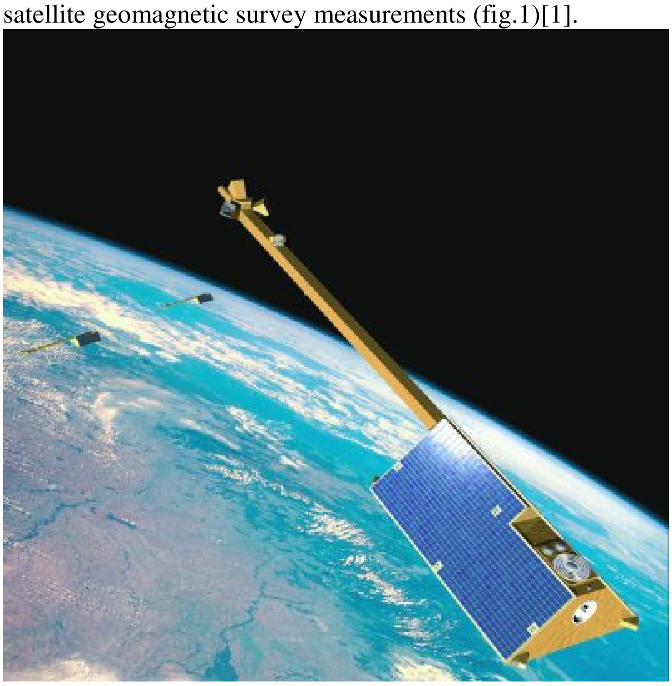

Fig. 1. Three low-orbit sub-satellites of SWARM space system

In case of MAGSAT, CHAMP satellite geomagnetic surveys of such capability is not present. However, in case of satellite geomagnetic surveys the recurring of a route on orbits, very close on coordinates, is possible that also allows successfully use the given DSTC method. In the solution of this problem the large help can be rendered by reliable MAGSAT, CHAMP satellite geomagnetic measurements [2, 3]. The doubtless virtue of satellite surveys consists of speed of realization of measurements on huge territories that saves of errors of the registration of the corrections connected with so-called changes of a secular variation of a geomagnetic field. But thus, observed by artificial satellites of the Earth (ASE) CHAMP, MAGSAT geomagnetic field is total reflection of various determined and random physical processes and appearances happening in various layers of the Earth. By one from methods of separation of a magnetic field of the Earth is a method of differential geomagnetic measurements.

Considered temporary epoch of geomagnetic survey executed by the satellite CHAMP or MAGSAT, it can be presented as a sum of sub-constant and variable fields stipulated by sources, located both inside the hard Earth, and outside of limits of the hard Earth (ionosphere-magnetosphere sources) [4]. It is possible to consider study spatial-temporal structures of the geomagnetic field (*Fs*), measured a board satellites [5, 6] as a sum of vectors of several fields

$$F_s(\varphi,\lambda,h,\ t)=F_m(\varphi,\lambda,h,\ t)+F_a(\varphi,\lambda,h,\ t)+F_v(\varphi,\lambda,h,\ t), \qquad (2)$$

where

- F_m – the component of vector of the induction of the main geomagnetic field generated by sources in the core of the Earth;
- F_a – the component of vector of the induction of the geomagnetic field generated by heterogeneities of tectonosphere (mantle) of the Earth;
- F_v – the component of vector of the induction of the variable geomagnetic field generated by sources external-earth ionosphere-magnetosphere origin and irregular earthquake signals. This field also frequently name as a “variable” electromagnetic field of the Earth;
- φ, λ, h, t – the geographic latitude, longitude, altitude and time of the satellite measurement point.

Usually for the mathematical description of a main geomagnetic field use a spherical harmonic series of the Gauss. For calculations the model of the main geomagnetic field with the length of a series equal to 13 harmonics developed [7]. For the analysis of a spatial structure of the geomagnetic field conducted mathematical processing and interpretation along 100 orbits ASE CHAMP covering territory from 1 up to 60 degrees of east longitude and within the limits of geographical altitudes from + 60 up to - 60 degrees (fig. 2).

Thus, the difference fields for each from selected of hundred orbits was calculated. The obtained thus difference fields are stipulated external magnetosphere current systems and internal sources of the Earth: by a magnetization at the Earth’s crust, electromagnetic heterogeneities in the mantle of the Earth, is present small component, connected with accidental errors of measurements.

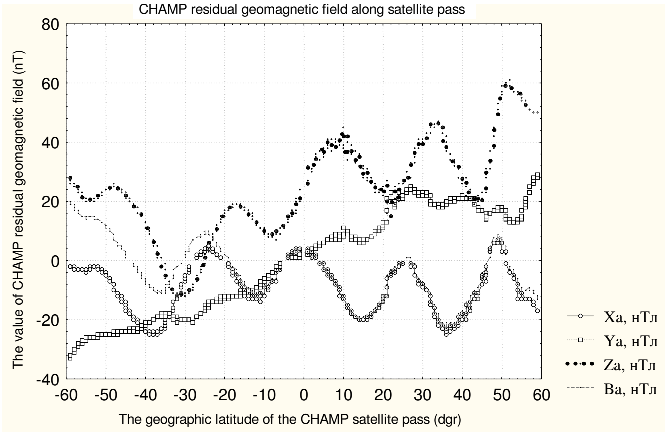

Fig. 2. The values of vector components of the CHAMP residual increment of geomagnetic field induction (F_r).

One from methods of allocation of a magnetic field connected with the interior-earth mantle heterogeneities of researched regions on the hum noise of the field connected with external-earth solar-magnetosphere-ionosphere sources and earthquakes too are the methods differential magnetic investigations [8, 10, 4, 6]. As, was shown above, from the satellite measured data (F_s) the main geomagnetic field (F_m) was previously eliminated. The residual field (F_r) is present in regional magnetic anomalies of mantle origin (F_a) and variation of a variable geomagnetic field (F_v). In the graph of change of values of the scalar (B_a) of the increment of geomagnetic field induction, the vector vertical component (Z_a) of the increment of geomagnetic field induction, the vector east component (Y_a) of the increment of geomagnetic field induction, the vector northern component (X_a) of the increment of geomagnetic field induction is shown, which a visible, that in all vector components of the increment of geomagnetic field induction is very complex at the noise. For extraction from the satellite geomagnetic data of the anomalies of the external origin and the earthquake signals we shall consider the formulas differential magnetic investigations, from which we leaned at computer calculations [8, 9, 4]. If the satellite is gone rectilinearly along S-N pass (an axis *X*) with the speed (υ) of the magnetometer installed on board of satellite, through a slice of time equal Δt=1 s can calculate through expression:

$$F(\varphi,\lambda,h,\ t)=F_s(\varphi,\lambda,h,\ t)\ [exp(-i\omega\Delta t)-1]exp(-i\omega t), \qquad (3)$$

where F_s - component of vector of the geomagnetic field induction, $\omega=(2\pi/T)$ - circular frequency of the measured geomagnetic field induction.

It is possible to determine of slice of times Δt_v and Δt_a, at which difference of the residual geomagnetic field under the data of the satellite CHAMP F_v and F_a will be less sensitivity of the magnetometer (ε) installed on board this satellite, from the formula (4):

$$\Delta t_v < \varepsilon / (\omega_v F_v), \qquad \Delta t_a < \varepsilon / (\omega_a F_a) \qquad (4)$$

However, there is one limitation of the DSTC method, when it is impossible to divide variations of the variable geomagnetic field called by sources of the external-earth origin and earthquake signals and measured on the satellite by anomalies of the “constant” field, created by sources in the tectonosphere of the Earth:

$$\omega_a \; F_a \; = \; \omega_v \; F_v \qquad (5)$$

The virtual spatial measuring base (ΔL) of a DSTC method for the satellite with the magnetometer will be on board determined from the following formula:

$$\Delta L \; = \; \upsilon \; \Delta t \;\; , \qquad (6)$$

where υ – the speed of motion of a satellite altitude orbit of the Earth equal 8 km / s.

Horizontal size (L) of a large interior-earth geomagnetic anomalies (for example, Kursk magnetic anomaly) in the projection to the Earth's surface is about 1000 km from the CHAMP satellite data (fig. 3).

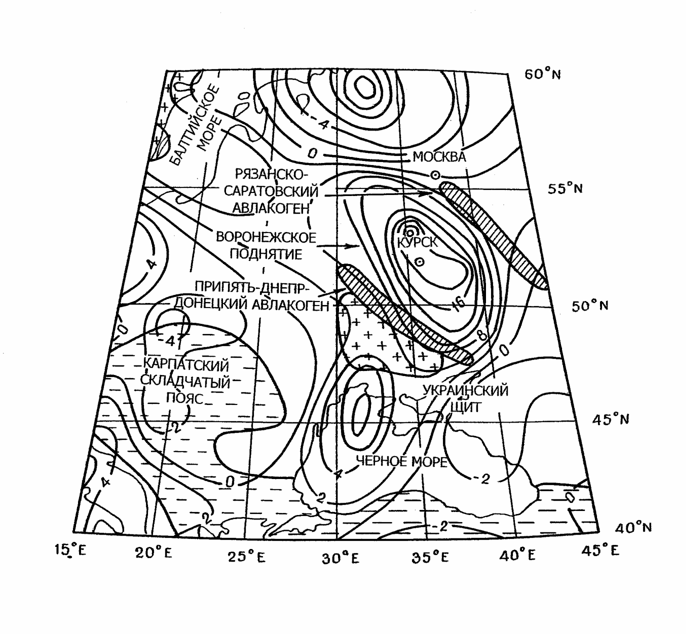

Fig. 3. The large interior-earth geomagnetic anomalies (for example, Kursk magnetic anomaly, Baltic shield magnetic anomaly, Ukraine shield magnetic anomaly) from the CHAMP satellite survey data

Then the temporal period (T) this interior-earth "constant" geomagnetic anomaly will be about 125 s from formula (7):

$$T = L \,/\, \upsilon \qquad (7)$$

The inequalities (4) determine working intervals of a DSTC method of processing of the satellite data. It is known, that the sensitivity (ε) of the component magnetometer installed on board a satellite CHAMP makes approximately 0.1 nT. It is known also, that the amplitude of diurnal variations of geomagnetic activity even of a perturbed variable geomagnetic field of mean and lower altitudes, as for example, in an observatory Moscow (IZMIRAN), makes about F_v = 30 nT. Then because of set forth above data it is easy to calculate values Δt_a and Δt_v. The outcomes of calculations for a various component (B_{av}, Z_{av}, Y_{av}, X_{av}) partial differential of the geomagnetic field on time are analysed. Though the Kursk magnetic anomaly is already looked through in some components, but the high-frequency filter of the Lagrange was applied for the best filtration of noise. It is justified, as at Δt = 1 s. The condition $Sin\ (\omega\ \Delta t) << 1$ is defaulted and the high frequencies are not filtered.

From the graphs the different component of the partial differential of a geomagnetic field per time (DSTC method) is visible, that the allocation of geomagnetic anomaly of interior-earth origin from the data some component of the differential field, is made better, than from the residual geomagnetic field, but nevertheless remains to far from an ideal, in connection with the noise of a researched realization of the geomagnetic field. That to improve the situation with extraction from the satellite data of the Kursk magnetic anomaly from a hum noise of the external-earth origin the algorithm of high-frequency filters of the Lagrange [11] to values of a combinational partial differential of a geomagnetic field per time, from the data of a satellite CHAMP was applied:

$$\partial F^{*}(\varphi,\lambda,h,t)/\partial t = \partial F(\varphi,\lambda,h,0)\partial t - 1.33[\partial F(\varphi,\lambda,h,\Delta t)/\partial t] + 0.33[\partial F(\varphi,\lambda,h,2\Delta t)/\partial t], \qquad (8)$$

where $(\partial F^{*}(\varphi,\lambda,h,t)/\,\partial t)$ - value of the combinational partial differential of the geomagnetic field per time, from the satellite data.

The graph of the realization of the combinational partial differential of a CHAMP geomagnetic field per time after application of the high-frequency filter of the Lagrange is shown in a fig. 4. It is well visible, that in this case are selected at almost full absence of external ionosphere-magnetosphere origin and internal tectonosphere signals from a curve combinational partial differential per time (latitude from ~ -20^0 to ~ +30^0). Figure 4 show that calculated values of the combinational partial differential of the geomagnetic field per time in separate zones apparently correlate with spatial distribution of seismic-tectonic effect of African rift faults. In particular the sharp changes DSTC values between on the max of curves from ~ +1^{0}N to ~ +20^{0}N (150-290 points) are connected with the effect of seismic-tectonic processes in African rift faults (fig. 4).

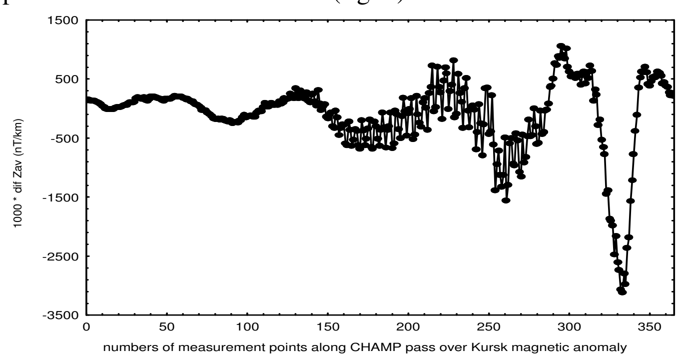

Fig. 4. The combinational partial differential of the geomagnetic field per time, from the CHAMP pass satellite data. They reflect of the seismic-tectonic effect of African rift faults (the sub-sinusoidal signals from points of satellite measurement 150 to 290 in the curve) and Kursk magnetic anomaly (from 320 to 350 points).

Conclusions

1. All components of the geomagnetic field (X_s, Y_s, Z_s, B_s), measured by MAGSAT, CHAMP satellites are noised by the sources of the variable geomagnetic field of the external origin and consequently is are low informative for extraction geomagnetic anomalies from seismic-tectonic effect of African rift faults.

2. The partial differential of the geomagnetic field per time (DSTC method) select better anomalies connected with seismic-tectonic effect of African rift faults and the Kursk

magnetic anomaly, than from the MAGSAT, CHAMP satellite measured geomagnetic field values.

3. The application of high-frequency filters of the Lagrange for values of the combinational partial differential of the geomagnetic field per time (combinational DSTC method), calculated from the CHAMP satellite data gives the most good outcomes of extraction of a field connected with seismic-tectonic sources interior-earth origin at the noise of the variable field of external-earth origin.

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