SOME PROJECTS PROPOSED BY GEOMAGNETIC DEPARTMENTS OF IZMIRAN THAT MAY USE SWARM DATA

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ABSTRACT

In the first section of a paper Main Geomagnetic Field and External Geomagnetic Field Departments of IZMIRAN mention (represent) some experience creation of geomagnetic field models. The second section consists of new ideas - as the data of SWARM can find application in researching a nature of Earth's magnetic field.

1. GEOMAGNETIC RESEARCH ACTIVITIES OF IZMIRAN'S GEOMAGNETIC DEPARTMENTS

1.1. Models of the Main Geomagnetic Field

1.1.1. Joint Spherical Harmonic – Natural Orthogonal Component method of making of the main magnetic field space-time model

A simple method is proposed for constructing a space-time model of the main magnetic field based on the high-accuracy satellite survey data. At the first stage, we expand the CHAMP daily mean data into spherical harmonics with constant coefficients. It provides us with a series of the daily mean spherical-harmonic models over a survey interval of several years, which are, then, expanded into the natural orthogonal components (NOC). The NOC series converges rapidly and the accuracy of the space-time model over the time interval under consideration is no worse than the accuracy of the traditional models.

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1.1.2. The continuous spatial-temporal models of the main geomagnetic field variations

The method of natural orthogonal components (NOC) analysis, which separates temporal variations, and spherical harmonic analysis, which models spatial distribution, were combined to model the spatial-temporal variations of the geomagnetic field over the globe. NOC's obtained in this way describe the temporal variations year by year without smoothing. The continuous spatial-temporal model of variations in the main geomagnetic field in the 20th century has been elaborated. All available data - from the navigation to the satellite surveys at the beginning and end of the century, respectively - have been used to construct the model. Since the accuracy of measurements was different during the century and the data are nonuniformly distributed over the Earth's surface, the methods for regulating solutions based on global parameters of the magnetic field and its secular variation, invariant on the simulation interval, have been used to correct the model. The secular variation model has been represented as the sum of the models obtained by means of expansion in terms of natural orthogonal components. The conclusions that the character of field variations is complex have been made and the spatial and temporal characteristics of the secular variations of different origin have been estimated based on the simulation results.

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1.2. Development of the magnetosphere magnetic field models and models of the high latitudinal ionosphere electric field and current systems

Two models of Variable Magnetic Field in near-Earth space are developed in IZMIRAN. First of them is developed from large-scale geomagnetic variation model derived from regression coefficients related high latitudinal ground-based geomagnetic field components to changes of the corresponding interplanetary magnetic field (IMF) and Solar Wind (SW). Ionosphere current distribution and density of field-aligned currents in the high-latitudinal ionosphere are calculated using large-scale geomagnetic variation model and ionosphere conductivity model. Then ionosphere plasma convection patterns and magnetic field generated by three-dimensional current systems at altitudes of ionospheric satellites are calculated (Belitza, 1992; Dremukhina et al., 1985, 1998a, 1988b, 1999; Feldstein and Levitin, 1986; Feldstein et al., 1984, 2005 and references therein). Second model of Variable Magnetic Field in themagnetosphere is developed on basis of Paraboloid Model created in Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University (Alexeev and Feldstein, 2001). Algorithm of calculation input parameters for Paraboloid Model is developed by IZMIRAN scientific team (Feldstein et al., 2005).

1.2.1. Model of high latitudinal large-scale geomagnetic variations

Model is derived from postulate that solar wind-geomagnetic variation coupling link can be considered as a lack box, which accepts changes of IMF and SW plasma parameters as input signal, and induces ground-based geomagnetic perturbations as an output signal. It is regression model where regression coefficients relate any ground-based geomagnetic field components to changes of the corresponding SW and IMF parameters for every (UT) hour for three seasons – summer, winter and equinox and for both northern and southern hemispheres. Model enable to evaluate geomagnetic disturbances (the magnetic field vector **H** amplitudes) in polar region above 57^0 corrected geomagnetic latitude in ground-based points with coordinates: Lat. = 89^o, 88^0, …58^0, 57^0 and MLT = 1, 2,…23, 24 for hourly mean values of Bz, By IMF components *(Feldstein and Levitin, 1986).*

1.2.2. Model of the electric field in high-latitudes ionosphere

Model of large-scale geomagnetic variations at ground level at high-latitudes is derived from a large quantity of high-latitude ground-based geomagnetic data**.** This regression model of geomagnetic variations is based as input for numerical solution of the second-order partial differential equation $\tilde{N}\ x\ (-S \times grad\ \varphi) = \tilde{N}\ x\ [\mathbf{n}_r\ x\ gradY]$, where φ is electrostatic potential (ionosphere electric field $\boldsymbol{E} = -\ grad\ \varphi$), S is a tensor of ionospheric conductivity, $\boldsymbol{n}_r$ is a unit radial vector, and Y is an equivalent current function, uniquely related to geomagnetic perturbations on the Earth's surface (*Feldstein and Levitin*, *1986)*. The model presents of the electric potential distribution patterns and distribution patterns of the electric field related with the electric potential for corrected geomagnetic latitudes $\geq 57^0$ in points with coordinates: Lat. = 89^0, 88^0, …58^0, 57^0 and MLT = 1, 2,…23, 24 at the ionosphere E-layer altitude for three seasons (summer, winter and equinox) for hourly mean Bz, By IMF components *(Feldstein and Levitin, 1986).*

1.2.3. Model of magnetosphere-ionosphere current systems in high-latitudes ionosphere

Model of high latitudinal ionosphere magnetosphere-ionosphere current systems is derived from calculating the ionosphere electric current $\boldsymbol{J}\wedge = \boldsymbol{SE} = S(-grad\ \varphi)$ and the field-aligned current $\boldsymbol{J}_{||} = Div\ \boldsymbol{J}\wedge$ using the model of the electric field in high latitudes ionosphere. Model presents distribution of $\boldsymbol{J}\wedge$ and $\boldsymbol{J}_{||}$ for corrected geomagnetic latitudes $\geq 57^0$ in points with coordinates: Lat. = 89^0, 88^0, …58^0, 57^0 and MLT = 1, 2,…23, 24 at the ionosphere E-layer altitude for each season of the year (summer, winter and equinox) for hourly mean Bz, By IMF components (*Feldstein and Levitin, 1986).*

1.2.4. Models of ionospheric convection and magnetic field at low-flying satellites orbit at high-latitudes

The model of the ionosphere plasma convection is derived from modeling particles drift velocity $\boldsymbol{V} = [\boldsymbol{ExB}]$ where B is the geomagnetic field vector and $\boldsymbol{E}$ is the electric field vector calculating by Model of electric field in high latitudes ionosphere. The model presents distribution of $\boldsymbol{V}$ for corrected geomagnetic latitudes $\geq 57^0$ in points with coordinates: Lat. = 89^0, 88^0, …58^0, 57^0 and MLT = 1, 2,…23, 24 at the ionospheric E-layer altitude for three seasons (summer, winter and equinox) for hourly mean Bz, By IMF components (*Feldstein and Levitin, 1986)*. The model of magnetic field generated by three-dimensional magnetosphere-ionosphere current systems is derived from modeling magnetic field connected with distribution of $\boldsymbol{J}\wedge$ and $\boldsymbol{J}_{||}$ currents calculating by Model of magnetosphere-ionosphere current systems in high-latitudes ionosphere (*Dremukhina et al., 1985).*

1.2.5. Model of Variable Magnetic Field in the magnetosphere

Model of Variable Magnetic Field in the magnetosphere is self-consistent version of a time-dependent magnetospheric paraboloid model (*Alexeev and Feldstein, 2001)*, and algorithm of calculation input parameters (*Feldstein et al., 2005*) The model uses DMSP satellite data to identify the location of the inner boundary of the magnetotail current sheet and the magnetic flux in the lobes, and their variations with time. These inputs plus upstream solar wind dynamic pressure and IMF Bz values are used for calculation of the magnetic field generated in given point of the magnetosphere.

1.2.6. Comparison of the models with experimental data

Comparison of the models with experimental data has been described in (*Dremukhina et al., 1985, 1998a, 1988b, 1999; Feldstein and Levitin, 1986; Feldstein et al, 1984, 2005, and references therein).*

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2. SOME PROJECTS PROPOSED BY IZMIRAN THAT MAY USE SWARM DATA

2.1. Estimation of relation of Main Earth's Magnetic Field models derived from satellites data with solar activity and solar wind parameters

To estimate relation of Main Earth's Magnetic Field models derived from satellites data with solar activity and solar wind parameters it is necessary to correlate coefficients of models Main magnetic fields for every day of a year with :

(a) solar wind and interplanetary magnetic field parameters;
(b) index of solar activity F10.7;
(c) angle between Earth's magnetic dipole and solar wind velocity.

All these factors influence on variable geomagnetic field and level its correlation with every days satellite models Main Earth magnetic field will be characterized level of presence in this models magnetic field from external source.

2.2. Estimation and calibration of magnetosphere current systems models using satellites magnetic data

The problem of estimation of accuracy modern models of magnetosphere magnetic field *(Feldstein et al., 2005; Alexeev et al., 2003; Hilmer and Voight, 1995; Yjsik, 1989; Ostapenko and Maltsev, 1997; Tsyganenko, 1990, 1995, 2002 and ref. therein)* may be partially solve by comparing model results with SWARM satellites data. Satellites data may by use to correct models and submodels. Each magnetosphere current systems models include submodels of magnetic field generated by current systems. Each submodel may be improved to create more perfect model of magnetosphere magnetic field.

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2.3. Estimation and calibration of models of the electric field, ionospheric convection, currents and magnetic field generated by high-latitudinal ionospheric current systems using satellites magnetic data

The problem of estimation of accuracy modern models of the electric field, ionospheric convection, current and magnetic field generated by currents systems in high-latitudes ionosphere *(Reiff et al., 1981; Wygant et al., 1983; Doyle and Burke, 1983; Heppner and Maynard, 1987; Feldstein and Levitin, 1986; De la Beaujardiere et al., 1991; Papitashvili et al., 1999; Weimer, 1995, 2001 and references therein)* may be partially solve by comparing modeled results with SWARM satellites data. Satellites data may by use to correct models and submodels. Each magnetospheric current systems models includes submodels of magnetic field generated by current systems. Each submodel may be improved to create more perfect Model of the electric field, convection and currents in high-latitudes ionosphere.

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2.4. SWARM data as the key point for the Eastward Electrojet study

The structure of ionospheric current system in high latitudes includes three main elements as the westward and eastward electrojets and currents in the cusp region. The connection of such currents with outer magnetosphere processes well established now but not clears in all details. Most controversy exists around eastward electojet, its physical sources and its role in the storm-substorm connection. The multisatellite data in SWARM project may lead to understand of the eastward electrojet connection with other elements of currents in ionosphere-magnetosphere system. According previous studies it was concluded that eastward electrojet might have two different types as explosive and convective ones. Such definition is in correspondence with our knowledge about two main physical mechanisms, which operate in the magnetosphere. The main features of eastward electroject are summarized in the table below:

Convective type	Explosive type
positioned around 12 - 18 LT	positioned around 21 - 00 LT
have corresponding convective westward electojet at morning hours	have corresponding explosive westward electrojet positioning about midnight
have not pronounced return currents at low latitudes	have clear return currents at middle and low latitudes
do not display Harang discontinuity	to form a Harang discontinuity
form the spread current sheet	form distinctive jet-like current
have strong seasonal dependence	have not seasonal dependence
have not accompanied by riometer asorption	accompanied by riometer absorption
have not pronounced conjugacy	display the clear conjugate features
have a connection with magnetosphere convection cell ???	have a connection with the partial ring current ???

The existence of two types of eastward electrojet (E-jet) confirmed by ground-based observations and some single point observations on satellites, but its role in the dynamics of storm-substorm connection is not clear. Some authors argue that E-jet connected with partial ring current, and the origin of E-jet mostly due to convection processes in the magnetosphere and does not play significant role in the substorm dynamics. The detailed SWARM data in combination with data from meridian chains of magnetometers will put a new light on the problems how E-jet operate in ionosphere and its role in the storm-substorm connection.

From ground-based data we can infer E-jet parameters as its intensity changes, position and size of electrojet along meridian, its seasonal changes and coupling with currents in the polar cap, middle and low latitudes. The case studies with SWARM data will lead to new insights on dynamics of ionospheric and magnetospheric currents. The comparison of dynamics of E-jets with currents in the magnetosphere obtained on the SWARM measurements will lead to a real picture in the space-time connection of current systems.

As a results we can understood the E-jet role in the general scheme of magnetosphere-ionosphere currents and the storm-substorm connection.

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