

Calculation of the power and angular components of the geomagnetic field induction vector in the territory of Ukraine

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The study calculates the geomagnetic field induction vector power and its angular components for the territory of Ukraine for the 2024.5 epoch. We used a digital map of the ΔB_a induction module anomalies and B_0 , the Earth's normal magnetic field. To calculate the components of the ΔB_a (the anomalous magnetic field), a 3D magnetic model of the territory of Ukraine was developed. It reflects regional and large local sources of the Earth's crust. The values of the Earth's normal magnetic field's components, B_{0x} (northern), B_{0y} (eastern), and B_{0z} (vertical), were calculated using the analytical model of the Earth's main magnetic field (IGRF-14). The power B_x , B_y , and B_z components of the geomagnetic field vector were obtained as the sum of their anomalous and normal values at points along a 10×10 km grid, and the angular, declination D and inclination I , were calculated.

Key words: geomagnetic field, IGRF-14, magnetic model, magnetic declination, Ukraine.

Introduction. The geomagnetic field is one of the main information factors in solving several problems of geomagnetism, Earth physics, the structure and development of the planet's inner and outer shells, forecasting minerals, and assessing environmental ecology. The Earth's inner magnetic field is the main magnetic field B_{IGRF} vector sum (the Earth's core field (International Geomagnetic Reference Field)) and the anomalous magnetic field ΔB (the Earth's lithosphere field). In [Orlyuk et al., 2024a], a map of the geomagnetic field induction module and its anomalies for the epoch 1969.5 was developed, and a method for constructing such maps for an any epoch was proposed. Using this technique, a map of the anomalous magnetic field for the epoch 2005.5 was created. By filtering the output field, it was divided into different wave components that carry information about the magnetic sources of the lower, middle, and upper parts of the Earth's

crust [Orlyuk et al., 2024b]. At present, developing maps of the Earth's geomagnetic field's power and angular components (north, east, vertical, horizontal, inclination, and declination) remains extremely relevant; they are used, in particular, for orientation, navigation, and the development of digital topographic maps [Chulliat et al., 2015; Meyer et al., 2017; Orlyuk et al., 2018].

Object of research: the magnetic field in the Ukrainian territory.

Purpose of research: calculating the Ukrainian territory power and angular elements of the internal geomagnetic field vector at the 2024.5 epoch.

Methods and materials. The internal magnetic field of the Earth is the vector sum of the core field (main magnetic field) B_0 and the anomalous magnetic field ΔB_a .

$$B = \sqrt{(\Delta B_{ax} + B_{0x})^2 + (\Delta B_{ay} + B_{0y})^2 + (\Delta B_{az} + B_{0z})^2}.$$

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To calculate B_x, B_y , and B_z (the power) and D and I (angular) components of the geomagnetic field induction vector B , we have the values of the anomalous ΔB_a and normal B_0 magnetic fields at our disposal. B_0 (the Earth's normal magnetic field induction vector modulus), B_{0x} , B_{0y} , and B_{0z} (its northern, eastern, and vertical components) are calculated using IGRF models. Until recently, the IGRF-13 model [Alken et al., 2021] has been available. Currently, the IGRF-14 model is available [Magnetic..., 2025], and it was used in our calculations. The digital map of the ΔB_a induction modulus anomalies was used to develop a 3D magnetic model of the crust and then calculate the anomalous magnetic field vector from it. In this case, taking into account the inductive and residual magnetization of individual sources, the calculation of the anomalous magnetic field vector is provided. From the Earth's normal magnetic field, the relevant components of the field model ΔB_{mx} , ΔB_{my} , ΔB_{mz} , ΔB_m are calculated, which, with some error, consort with the ΔB_{ax} , ΔB_{ay} , ΔB_{az} , and ΔB_a components.

The calculation of B magnetic field induction vector modulus and the absolute values B_x of its northern, B_y eastern and B_z vertical components is carried out by adding at the calculation points the according components (B_{0x} , B_{0y} , B_{0z}) of the normal and (ΔB_{ax} , ΔB_{ay} , ΔB_{az}) anomalous fields

$$B = B_0 + \Delta B_a, \quad B_x = B_{0x} + \Delta B_{ax}, \\ B_y = B_{0y} + \Delta B_{ay}, \quad B_z = B_{0z} + \Delta B_{az}.$$

The horizontal component value and the Earth's magnetic field total vector of the D declination and I inclination angles are calculated by equations

$$B_H = \sqrt{B_x^2 + B_y^2}, \quad D = \arccos(B_x/B_H), \\ I = \arcsin(B_z/B).$$

Results. This work presents the results of calculating the Earth's magnetic field's vector power components, as well as the inclination and declination angles for the Ukrainian territory, considering the influence of the anomalous magnetic field crustal sources. For this purpose, a 3D magnetic model of the Ukrainian territory was created, which was the

basis for the ΔB_a anomalous field components calculations [Orlyuk et al., 2017]. The model is represented by 230 magnetic sources. The obtained field satisfies the regional component of the anomalous magnetic field with acceptable accuracy (± 50 nT), as well as large, intense local anomalies (± 150 nT). Sources of magnetic anomalies are located at depths from 1 to 10 km (local magnetic anomalies) and from 7—10 to 30—45 km (regional anomalies). The sources' magnetization ranges from 0.1 to 10.0 A/m. The Kursk and Kryvyi Rih anomalies' sources have a magnetization of more than 10.0 A/m. The B_x , B_y , B_z , D , and I geomagnetic field components are calculated for the 2024.5 epoch (Fig. 1—3).

According to the calculations, the B geomagnetic field induction modulus for the Ukrainian territory at the 2024.5 epoch varies from 47900 to 57400 nT (Fig. 1). At the same time, the background magnetic field varies from 49600 nT in the southwest to 51600 nT in the northeast. The largest anomalies are according to the sources of Kursk and Kryvyi Rih-Kremenchuk magnetic anomaly bands.

The influence of such magnetic anomalies is also reflected in other geomagnetic field induction module B components. The B_x northern component varies from 17500 to 25200 nT with background values from 18100 nT in the north of Ukraine to 22500 nT in the south (Fig. 2, a). The greatest influence from the anomalous magnetic field crustal sources was experienced by the B_y eastern component. It varies from -1800 to 7800 nT

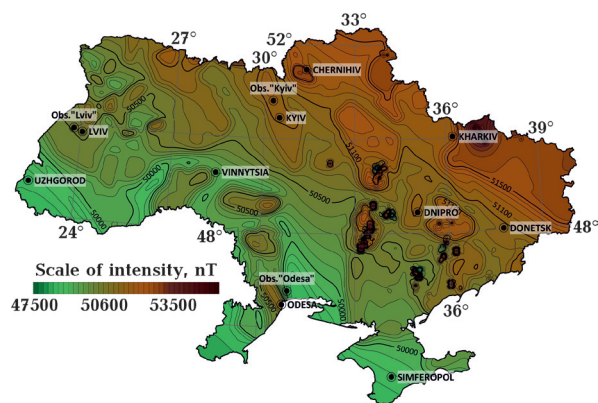


Fig. 1. Digital map of the B geomagnetic field's induction module for the Ukrainian territory at the 2024.5 epoch.

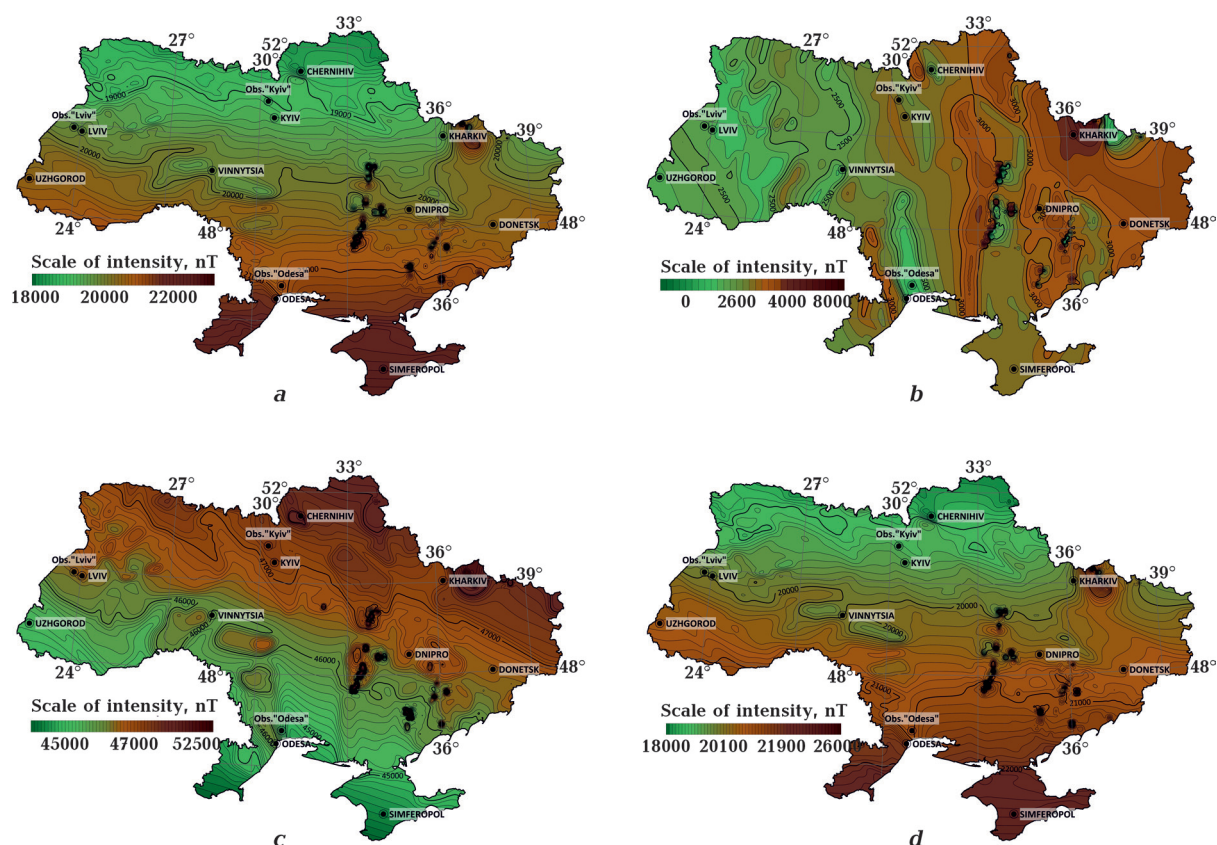


Fig. 2. Northern (a), eastern (b), vertical (c), and horizontal (d) geomagnetic field induction vector components for the Ukrainian territory at the 2024.5 epoch.

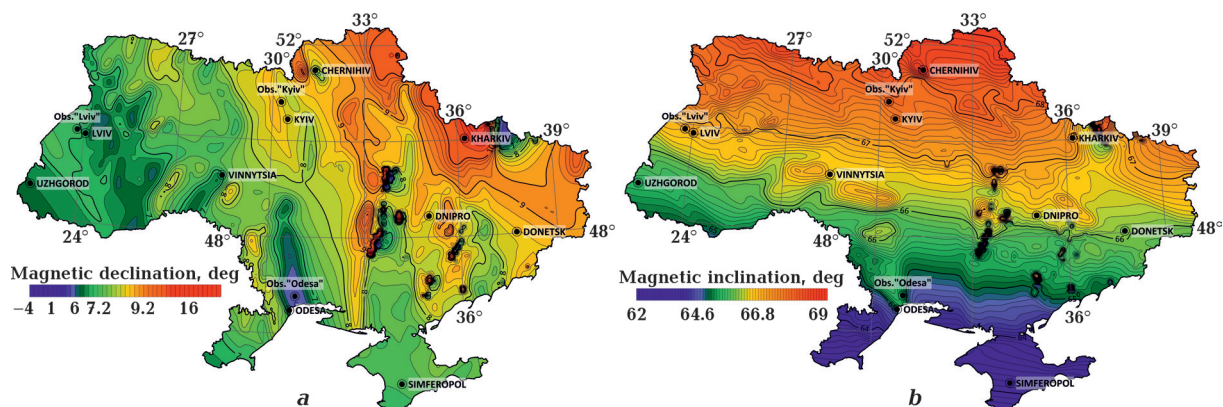


Fig. 3. The geomagnetic field's declination D and the inclination I for the Ukrainian territory at the 2024.5 epoch.

with background values of 2300 nT in the west of Ukraine and 3200 nT in the east (Fig. 2, b). The B_z component is similar to the B geomagnetic field induction modulus. Its values vary from 44000 to 53400 nT against the background of its normal values of 44300 nT in the south and southwest to 48100 nT in the northeast (Fig. 2, c). The B_H component is

within 18252—25712 nT, from south to north, naturally increasing and in intense magnetic anomalies areas (Fig. 2, d).

According to the calculations, the D magnetic declination on Ukrainian territory varies from -4° to 21° (Fig. 3). For example, for the Odesa Regional Magnetic Anomaly, the intensity of which is up to 700 nT at the maxi-

mum, the D anomalies are from -2.6° to 1.2° . The inclination at the 2024.5 epoch varies from 62.1° to 69.6° with background values from 62.7° in the south of Ukraine to 69° in the north (see Fig. 2, d).

Calculated values of the Ukrainian territory geomagnetic field power and angular elements are crucial for solving numerous geology, geophysics, and geomagnetism problems. The digital data of the geomagnetic field vector and its declination induction module plays nowadays a particular role. It is necessary for assessing the environment's ecology and for developing topographic maps.

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Розрахунок силових та кутових компонент вектора індукції геомагнітного поля території України

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У дослідженні викладено результати розрахунку силових та кутових компонент вектора індукції геомагнітного поля території України на епоху 2024,5 року. Для цьо-

го використано цифрову карту аномалій модуля індукції ΔB_a та нормальне магнітне поле Землі B_0 . Для розрахунку компонент аномального магнітного поля ΔB_a було розроблено 3D магнітну модель території України, в якій відображено регіональні та великі локальні джерела земної кори. Значення компонент нормального магнітного поля Землі B_0 , його північної, східної та вертикальної складових, були розраховані за аналітичною моделлю головного магнітного поля Землі IGRF-14. Силі B_x , B_y та B_z компоненти вектора геомагнітного поля були отримані як сума їх аномальних та нормальних значень в точках за мережею 10×10 км, а кутові, схилення D та нахилення I — шляхом розрахунку.

Ключові слова: геомагнітне поле, IGRF-14, магнітна модель, магнітне схилення, Україна.