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Intermittence and Peculiarities of a Statistic Characteristic of the Geomagnetic Field in Geodynamo Models

A. V. Khokhlov[a, b, *], F. Lhuillier[c], and V. P. Shcherbakov[b, d, e]

[a]*Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences, Moscow, 117997 Russia*

[b]*Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, 123995 Russia*

[c]*Ludwig-Maximilian University of Munich, Germany*

[d]*Kazan (Volga Region) Federal University, Kazan, 420111 Russia*

[e]*Borok Geophysical Observatory, Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, Borok, Russia 152742*

**e-mail: fbmotion@yandex.ru*

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Abstract—The analysis of the statistical characteristics of the geomagnetic field generated in the numerical geodynamo models has shown that the distribution of the spherical harmonic coefficients in some cases is not Gaussian but, instead, has much in common with the Laplace distribution. The shape of the corresponding histograms depends on the time scale, which allows interpreting the obtained data in terms of a mixture of Gaussian distributions. The similar effects associated with the intermittence were observed in the experiments in a turbulent fluid flow. Hence, the behavior of secular variations in the magnetic field of the Earth should perhaps be described in terms of a mixture of several Gaussian stationary processes corresponding to switching between the different regimes of geodynamo generation.

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INTRODUCTION

Secular variations of the geomagnetic field are one of the most important behavioral characteristics of the geomagnetic field, and are therefore a major focus of the research concerned with the main geomagnetic field. We recall that the notion of secular variations captures fluctuations in the components of the vector magnetic field **B** that occur on the time scales from one year to 10 ka. Therefore, their investigation, besides instrumental observations, also extensively relies on the archaeo- and paleomagnetic data. The role of a formal instrument in studying secular variations is played by the spherical harmonic analysis in which the geomagnetic field vector **B** is fully described in time and space through the expansion of its potential V in spherical functions with the time dependent coefficients g_n^m and h_n^m:

$$V(r,\theta,\psi) = \frac{R_{\mathrm{E}}}{\mu_0}\sum_{n=1}^{\infty}\sum_{m=0}^{n}\left(\frac{R_{\mathrm{E}}}{r}\right)^{n+1} \times P_n^m(\cos\theta)\left(g_n^m\cos m\psi + h_n^m\sin m\psi\right). \quad (1)$$

Here, R_{E} is the Earth's radius, r is the distance from the center of the Earth to the point where the value of potential V is calculated; μ_0 is a magnetic constant; and ψ and θ are angular spherical coordinates with the polar axes aligned with the rotation axis of the Earth. In geomagnetism, special conventions are assumed for the Legendre polynomials:

$$P_n^m(\cos\theta) = \begin{cases} \tilde{\mathrm{P}}_n^m(\cos\theta), & m = 0 \\ \sqrt{\dfrac{2(n-m)!}{(n+m)!}}\tilde{\mathrm{P}}_n^m(\cos\theta), & m > 0 \end{cases}, \quad (2)$$

where $P_n^m(\cos\theta)$ are the associated Legendre polynomials of the argument $\cos\theta$.

Several physical considerations and the analysis of empirical regularities observed in the time variations of the coefficients of this expansion brought about the so-called giant Gaussian process (GGP) hypothesis (Constable and Parker, 1988) in which the expansion coefficients g_n^m and h_n^m are considered as statistically independent Gaussian processes, and in particular, the realizations with a sufficiently long time step obey the distribution law $y(x)$ = constexp$(-bx^2/2)$. The GGP models have been repeatedly tested based on the comparison of their results with the empirical data on paleodirections (Khokhlov et al., 2006; Khokhlov, Hulot, 2013) and world databases on paleointensity (WDB PINT) (Khokhlov and Shcherbakov, 2015;