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Statistics of dipole and non-dipole geomagnetic energy

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The total energy of the potential geomagnetic field is divided into dipole and non-dipole parts. The statistical properties of the both energy parts, their powers and characteristic frequencies are determined and compared basing on the COV_OBS (1840-2020) model [1].

Previously, from an evolutionary analysis presented in [2], we showed that the dipole energy decreases quite slowly and monotonically, while the non-dipole energy changes faster and quasi-periodically. The characteristic times of the dipole and the entire field are about a thousand years, which is consistent with the known times [3-4]. Non-dipole times of the order of hundreds of years have not been previously identified. The purpose of this work is to identify the statistical properties of the corresponding energies, powers and characteristic times.

The cumulative distribution functions were chosen as tools of our statistical analysis. They were derived for the total energy E, its dipole part E1, the non-dipole part E-E1, the sum of the quadrupole and octupole E2+E3, for all corresponding powers or the time derivative of the corresponding energies (P, P1, P2, P3) and for frequencies (S, S1, S2, S3), which were defined as the corresponding ratios of powers to energies.

The root mean square RMS is 7.0 EJ for E and is close to the arithmetic mean, median and most probable with a small standard deviation Q = 0.3 EJ. E1 is characterized by the same statistic parameters and a monotonic profile of the cumulative function, coinciding with evolution. P and P1 with their close profiles and RMS~200 MW are in even better agreement with each other. The RMS values derived for S and S1 is such that they correspond to a characteristic time of about a thousand years. Thus, from the behavior of the dipole component it is quite possible to consider almost the entire global potential field, which is very positive for paleomagnetic reconstructions.

The situation is much worse with all non-dipole E-E1. Its behavior cannot be confidently assessed using E2+E3, the most accessible to paleomagnetologists. In our study, E2+E3 is characterized by RMS=0.6 EJ, which is almost 3 times less than for E-E1. The profiles of the cumulative functions also differ significantly, and the RMS for total non-dipole power P2=d(E-E1)/dt is equal to 220 MW, which is more than twice the RMS for P3=d(E2+E3)/dt. It is interesting to note that the powers of the dipole and the entire field are quite close to the power of the non-dipole field. In this case, Q is very large (~200 MW) for the entire P and its small part P3, but several times less for P1 and P2.

Manifestations of the non-dipole component (both E-E1 and E2+E3) can be identified by their inherent frequencies S2 and S3, which are approximately four times higher than frequencies for the dipole components. Accordingly, we obtain a characteristic time of the order of 250 years for global non-dipole components.

The problem of extending the results obtained on a relatively short time interval to longer periods studied in paleomagnetism remains not fully resolved. This problem is supposed to be solved in the future by systematically comparing the properties of short-term and long-term models, as, for example, this was done in [5].

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