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Solar magnetic quadrupole and interplanetary field

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Abstract. Long-term behaviour of the interplanetary magnetic field is compared with that of the quadrupole harmonic of the solar axisymmetric magnetic field. Substantial correlation between them is found both on the time scale of 22-yr cycle and on the shorter time scale of several years.

The interplanetary magnetic field (IMF) measured near the Earth's orbit exhibits variations occurring on the time scale larger than one year (Juckett 1998; Kuklin & Obridko 1988). The long-term variations of such sort also are characteristic of the mean magnetic field of the Sun (Kotov 1994; Haneychuk 2000). These facts sometimes are treated as evidence for "monopole-like" behaviour of the solar large-scale magnetic field (LSMF), but, it is more reasonable to explain they by existence of the quadrupole-like axisymmetric magnetic field of the Sun (Juckett 1998; Kuklin & Obridko 1988; Haneychuk 2000). The aim of the present paper is to compare the long-term evolution of IMF with that of the quadrupole-like (symmetric relative to the equator) modes of the solar magnetic field.

1. Data

Daily values of three components of IMF measured by spacecrafts in years 1967-2001 have been obtained from NSSDC OMNIWeb site. The data given in the GSE system have been reduced to the solar equatorial coordinate system with the r axis directed away of the Sun, the φ axis directed from E to W, and θ axis directed from N to S. Below I analyze the annual mean values of the radial, B_r, azimuthal, B_φ, and meridional, B_θ, components of IMF.

Amplitudes of the axisymmetric modes of the LSMF, C_n, have been derived by expanding magnetic field in spherical harmonics. For this purpose, I used synoptic maps of the solar magnetic field obtained at three observatories, Mount Wilson (MWO), Kitt Peak (KPNO), and Stanford (WSO). The data cover a time interval from 1967 to 2001.

In addition to the data series described above, I examine indirect data concerning the solar and interplanetary magnetic fields. Using polarities of IMF inferred by Svalgaard from geomagnetic variations, I have calculated annual values of the dominant polarity, S, for years 1926-1971. They are compared with relative values of C_n inferred by Makarov *et al.* (2001) from a series of H-alpha synoptic maps.

2. Results

Figure 1 exhibits a comparison between IMF and amplitude of the solar magnetic quadrupole, C_2. Principal results of the data analysis are as follows.

* There is a substantial agreement between variations of the azimuthal IMF, B_φ, and

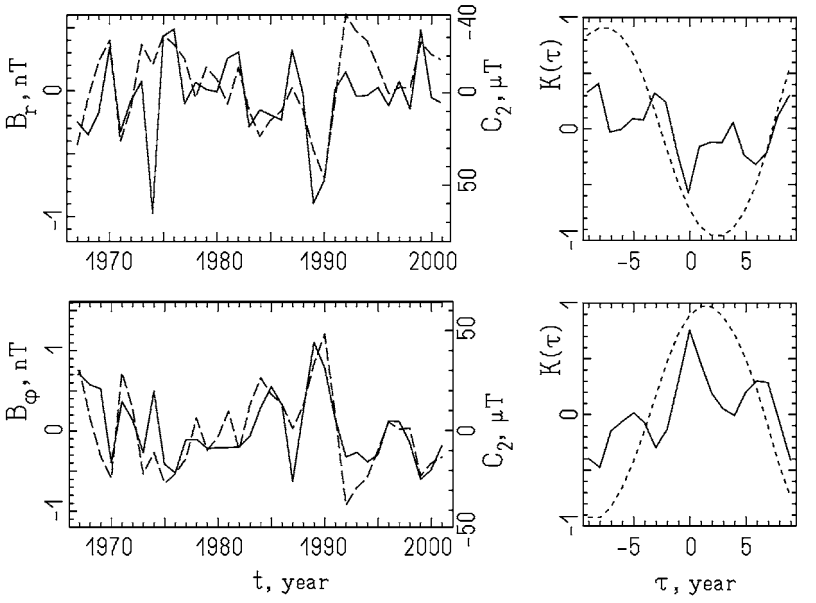

Figure 1. Left panels show radial IMF, B_r (top), and azimuthal IMF, B_φ (bottom) in comparison with amplitude of solar quadrupole, C_2 (indicated by dashed line). Right panels exhibit cross-correlation functions for the time series under comparison (solid line) and for their low-frequency components (short-dashed line)

those of the solar magnetic quadrupole, C_2: Correlation coefficient $r(B_\varphi, C_2) = 0.76$ Correlation between C_2 and radial IMF, B_r, is less pronounced, although appreciable: $r(B_r, C_2) = -0.57$. The signs of the correlation coefficients are the same as might be expected proceeding from the source surface model. As far as the meridional component of IMF is concerned, no correlation between B_θ and C_2 is found.

** The indirect data also reveal an appreciable correlation between the dominant polarity of IMF, S, and C_2: $r(S, C_2) = -0.53$ for the period from 1926 to 1971.

*** The solar quadrupole and IMF both reveal variations of two kinds: the comparatively short-term oscillation with period ≈ 6 y and long-term variation with period of about 22 y. While the former shows no mutual phase shift between IMF and C_2, the latter exhibits a time delay of IMF relative to C_2 by about 2 y.

**** Although the behaviour of IMF undoubtedly is affected by the magnetic quadrupole of the Sun ($n = 2$), little or no correlation is found between IMF and higher-order ($n > 2$) harmonics of the photospheric magnetic field.

References

Haneychuk, V. I. 2000 *Izv. Krymsk. Astrofiz. Obs.* **96**, 176–187.

Juckett, D. A. 1998 *Solar Phys.* **183**, 201–224.

Kotov, V. A. 1994 *Izv. Krymsk. Astrofiz. Obs.* **91**, 124–143.

Kuklin, G. V. & Obridko, V. N. 1988 In *Fizika solnechnoi activnosti* (ed. E.I. Mogilevsky) pp. 146–167. Moscow, Nauka (*in Russian*).

Makarov, V. I., Tlatov, A. G., Callebaut, D. K., Obridko, V. N. & Shelting, B.D. 2001 *Solar Phys.* **198**, 409–421.

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