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Decadal-period external magnetic field variations resolved with eigenanalysis

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Variations in the magnetic field at and above the Earth's surface permeate the interior of our planet, and can be used to determine the electrical conductivity of the mantle. Presently, the annual and semi-annual period fields induced by magnetospheric and ionospheric currents, suitable to estimate mantle conductivity in the approximate depth range 1,200–2,000 km, are subject to large uncertainty since they overlap with the periods on which the core field also changes significantly. It is timely to obtain an improved determination of the spatial geometry of the external, inducing, fields in order to better separate their internal, induced, part from that generated in the core.

We apply the method of Empirical Orthogonal Functions (EOFs) to a dataset of ground-based magnetic observatory hourly means in order to decompose the external magnetic field during quiet times over a full 11-year solar cycle into its modes of maximum variance. This allows us to assess the spatial structures and magnitude changes of its dominant spatio-temporal patterns. Specifically, our focus is on isolating the long period external inducing fields as they penetrate to the depths of the mantle where the conductivity is least constrained.

We expand ground-based measurements in the inertial local-time frame to produce spherical harmonic models of the dominant long period signals isolated by the EOF method. Whilst the ring current dominates the decomposition, we show that an annual and a semi-annual oscillation are important in describing the full inducing field. Each of these terms exhibits a modulation from the 11-year solar cycle. In summary, the most important harmonic in the description of the inducing fields is P_1^0, followed by P_2^1. There are lesser but still significant contributions from the P_1^1 and P_2^0 harmonics.