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Detecting Externally Forced Long Term Palaeomagnetic Variations: Insight from Dynamo Simulations

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Abstract

The internal geomagnetic field varies over a huge range of timescales but it is only at the longest of these (10^7 to 10^9 years) that we expect to encounter a signature of geodynamo forcing from mantle convection and Earth's secular cooling. Precise and accurate identification of such variations and their causes represents one of the great outstanding challenges for palaeomagnetism and deep Earth science.

Here we assess for the first time a broad swathe of new and published geodynamo simulation outputs (Davies *et al*. 2008, Heimpel and Evans 2013) using palaeomagnetic techniques. These simulations span a wide range of input parameters and boundary conditions producing magnetic field variability at Earth's surface that ranges from highly unstable, through nonreversing, to fully "locked" by mantle heterogeneities (Fig. 1). Nevertheless a common feature of the displayed behavior is a tendency for "low frequency secular variation": variations in directional scatter and intensity that change over the equivalent of hundreds of thousands of years. Such variations are also an observed characteristic of the geomagnetic field over the last 2 million years (Valet *et al*. 2005) and reflect the highly nonlinear nature of the geodynamo process.

We will present evidence that low frequency secular variation has the potential to bias previous attempts to recover properties of the time-average field and also to confound efforts to detect the even longer timescale variations that promise to yield information about the evolution of the deep Earth. We will also discuss what needs to be done to avoid such problems in future analyses and outline a strategy for palaeomagnetists to follow in the future.

Keywords: palaeomagnetism, geodynamo, secular variation, palaeointensity, reversals.

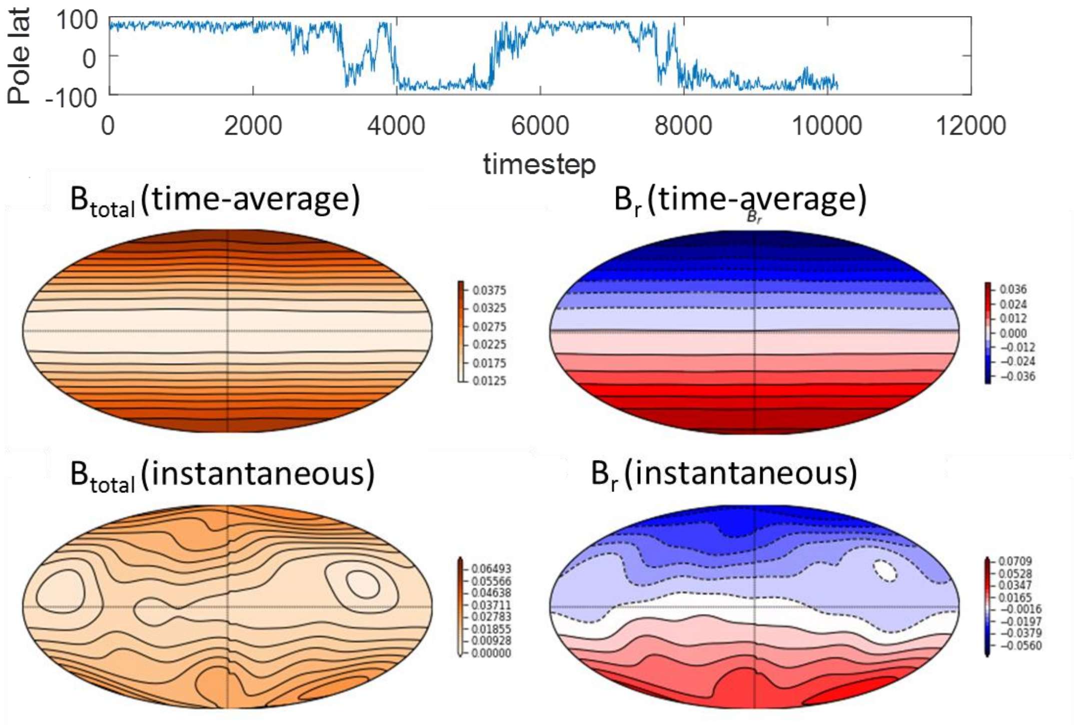

Fig. 1. Time series of pole latitude and visualizations of total and radial field intensity in a numerical simulation with the following parameters: magnetic Prandtl number, 10; Ekman number, 5×10^{-4}; Rayleigh number, 350. Note that both field strength and time are non-dimensional but that the total duration would scale to approximately 3 million years.

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