Mandea, M., Olsen, N. (2009): Geomagnetic and Archeomagnetic Jerks: Where Do We Stand?. - Eos, Transactions, American Geophysical Union, 90, 24, 208-208

From geomagnetic jerks to archeomagnetic jerks: where do we stand?

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March 4, 2009

The Earth's magnetic field is mainly generated by a self-sustaining dynamo in the fluid outer core. This part, known as the core or main field, is not constant but changes with time, a phenomena denoted as *secular variation.* There is, however, no common agreement about the definition of the term *secular variation* in the geomagnetic literature: while some authors use this term for the temporal changes of the core field in general, others refer to its linear part (first time derivative), only. Two more terms are link to the core field temporal variations: geomagnetic jerk and archeomagnetic jerk. They have been introduced to describe a specific magnetic field signature in the observations (which means that a phenomenological classification is used). We suggest that a characterization of magnetic field changes based on the physics of the underlying core process may be more useful and such a classification is proposed here, in order to avoid misunderstanding in terminology.

Let us recall, that whether something is perceived as a trend or not depends on the timescale in consideration: what appears to be a linear change over a timescale of years to decades may turn out to be more complicated when looking at the century to millennium timescale. Indeed, the secular variation for the last few centuries – over which direct measurements are available – is far from linear, and abrupt changes in its rate of change have been observed and discussed. These events characterized by a sudden change in the trend of the first time derivative of the magnetic field, correspond to a step in the second time derivative, and have been named *geomagnetic jerks.* It becomes generally agreed that these events originate in the Earth's core and that they occur over short timescales. But how short is "short"?

Recently, using additional information provided by geomagnetic field models and latest satellite data (Mandea and Olsen, 2006; Olsen and Mandea, 2007), new characteristics of the secular variation have been found, both regarding spatial resolution and the duration of "sudden" changes. In this context a problem arises: should every *very short-term fluctuations of the core magnetic field* that occurs on timescales of just a few months to a couple of years, be called for a *geomagnetic jerk*?

The terminology has become further complicated by the use of the term *archeomagnetic jerk* (Gallet et al., 2003). The idea behind this designation is to denote sharp features at a timescale intermediate between geomagnetic jerks (1 to 2 yrs in a centennial time series) and excursions (10^3 to 10^4 yrs in a time series of 10^5 to 10^6 yrs length). However, the term *archeomagnetic jerk* is used to characterize a sudden change in the magnetic field itself, contrary to the classical definition of a *geomagnetic jerk*. The term *archeomagnetic jerk* may therefore be misleading.

As an example for *geomagnetic jerks* observed from historical data, the zoom part of Figure 1 shows the temporal changes of the declination annual means, dD/dt, since the first observatory was installed in the Paris region. Also shown are predictions of dD/dt for Chambon-la-Forêt observatory, as given by the *gufm1* (Jackson et al. (2000)) and the preliminary *CALSK10* model (M. Korte, pers. comm.).

These curves indicate that there are linear segments of constant slope of dD/dt, lasting from a few decades (e.g. 1925 to 1970) to a century (e.g. the 18th century), as well as short-term abrupt changes on decadal or even subdecadal timescales. The estimations deduced from the preliminary *CALSK10* model indicate periods characterized by important accelerations, as around 7000BC, with a change of about $0.5°$ in some 100 years, or, starting with the 18th century, of more than $0.3°$ in less the 200 years.

In the following we suggest a classification of the magnetic field temporal changes based on the physics of the underlying core process.

Geomagnetic jerks have been explained by invoking torsional oscillations in the fluid outer core (Bloxham, 2002). The torsional oscillations consist of time-dependent axisymmetric and equatorial symmetric zonal flows, with typical periods of several decades. Theoretical considerations suggest that such oscillations should be contained in core flows, and because of their timescale they can be observed in historical data. For core dynamics the torsional oscillations are very important as they are the most robust observed dynamic feature inside the core and provide a crucial link between magnetic field observation and dynamo theory. We suggest that changes in the geomagnetic field due to the torsional oscillations are denoted *geomagnetic jerks*.

Torsional oscillations may only give a snapshot of the dynamo on a decadal timescale. No direct information are available for very short timescales (less than a couple of years) or at the timescale of magnetic field generation (more than thousands of years). Magnetic field changes arising on these timescales are discussed in the following, with a suggestion on how to denote them.

Rapid secular variation fluctuations Can we find flows in the core that are consistent with very rapid changes of the field, as observed newly using

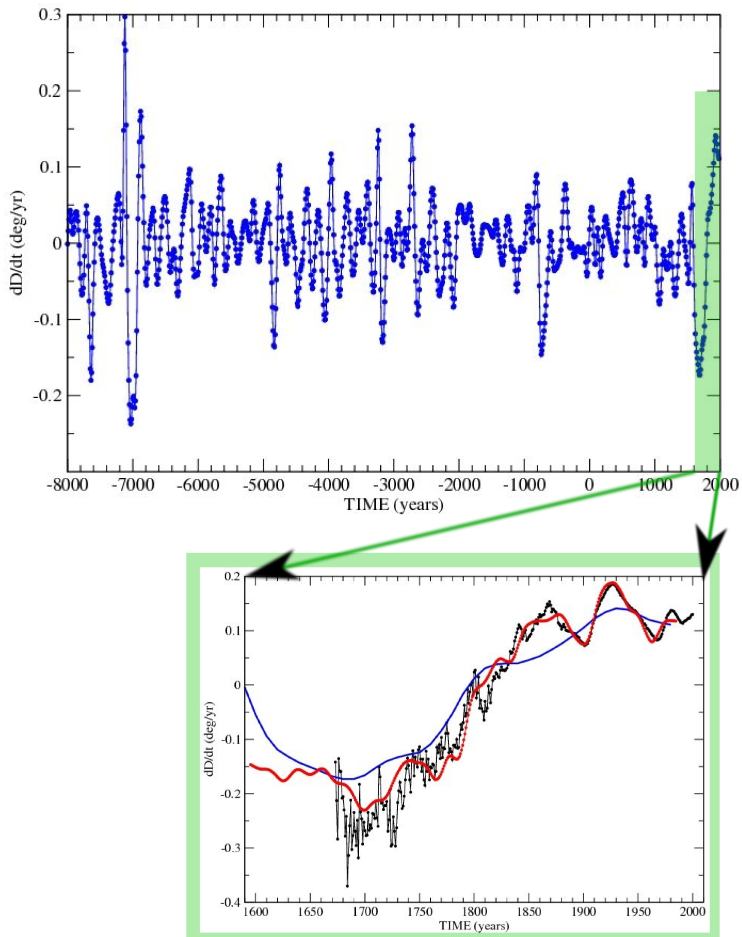

Figure 1: Temporal evolution of the declination for the site of Chambon-la-Foret given by the preliminary *CALSK10* model (blue dots). The zoom part indicates the secular variation recorded in Paris region and adjusted to the Chambon-la-Forêt observatory (black dots), and the corresponding estimations for the same site given by the *gufm1* model (red curve) and the preliminary *CALSK10* model (blue curve).

magnetic satellite data (Mandea and Olsen, 2006; Olsen and Mandea, 2007) and in agreement with the observed change in the Length-of-Day (LOD)? Recently, Olsen and Mandea (2008) have shown that changes in the magnetic field occurring over only a few months as well as the fluid flow at the top of the core generating them, can be resolved. The derived time-dependent core flow, fitting the recent secular variation behavior and being in agreement with the LOD variation, is spatially rather localized and involves rapid variations over short timescales of only a few months, with surprisingly large local accelerations. We suggest to call these changes *rapid secular variation fluctuations* or shortly *rapid fluctuations*.

Archeomagnetic jerks Can we find flows that are consistent with changes observed in the secular variation covering a few millennia, and also with the LOD variations on a millennial timescale? Dumberry and Bloxham (2006) have shown that the amplitudes and characteristic timescales of the observed LOD changes can be explained by zonal flow variations deduced from secular variation, on millennial timescales. Changes in the magnetic field configuration are generated by convective motions, which in turn produce observable secular variation. Recently, Wardinski and Korte (2008) found that a toroidal flow explains better the long-term variation in the geomagnetic field secular variations compared to a geostrophic flow. The significant periodicities for the large scale zonal flows range from some 540 to 1050 years. We suggest that the term *archeomagnetic jerk* should be used to denote these long-term changes in the secular variation, rather than the field direction, as initially suggested.

We hope that our suggestion on terminology of geomagnetic field changes will help to better track the different temporal variations revealed by observations, as well as in developments concerning the dynamics of the fluid core.

Acknowledgments We would like to thank Monika Korte for providing the preliminary CALSK10 model.

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