The importance of satellite magnetic data to improve our confidence in a possible reversal or excursion of the present geomagnetic field

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Abstract

Introducing the concept of information content I(t) derived from Gauss coefficients it is possible to follow the present behaviour of the geomagnetic field in a very subjective way, and, potentially, to predict it. The linear decrease of I(t) for the last few centuries could be considered an evidence for a chaotic state of the dynamical system generating the geomagnetic field and possibly related to a possible imminent reversal or excursion of the field. Present satellite missions and, even more, future missions such as Swarm will probably uncover this aspect with better precision.

Mean Square value of B

Over the globe (Lowes, 1966):

$$\left\langle B^2(t)\right\rangle = \frac{1}{4\pi}\int_0^{\pi}\int_0^{2\pi} B^2(\theta,\lambda,t)\sin\theta d\theta d\lambda$$

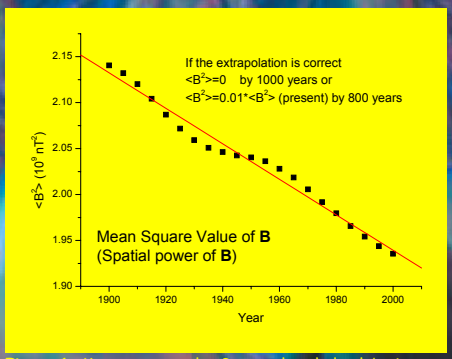

Figure 1. Mean square value B over the whole globe in the period 1900 to 2000 (De Santis et al., 2004) from IGRF (Macmillan & Maus, 2005).

Over Antarctica ($\theta_0 = 5\pi/6$) :

$$\left\langle B^2(t)\right\rangle_{\theta_0} = \frac{1}{2\pi(1-\cos\theta_0)}\int_{\theta_0}^{\pi}\int_0^{2\pi} B^2(\theta,\lambda,t)\sin\theta d\theta d\lambda$$

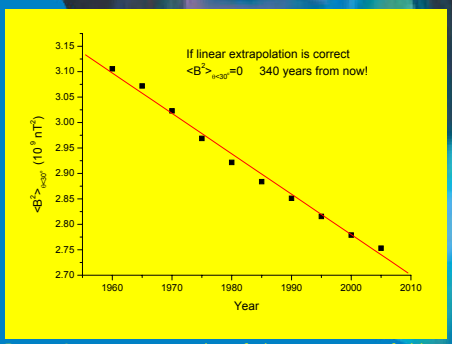

Figure 2. Mean square value of the geomagnetic field over Antarctica from 1960 to 2005 from the Antarctic Reference Model (ARM ; De Santis et al., 2002) expressed in Spherical Cap Harmonics. This model is based on ground and satellite (Oersted and Champ) magnetic data.

The mean square value of B over Antarctica will be zero by **340 years** from now.

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Background picture taken from Scientific American, issue of 31/05/2003.

Information Content of B

From Shannon theory (Shannon, 1948):

$$I(t) = \sum_{n=1}^{N} p_n(t)\cdot \ln p_n(t)$$

where (De Santis et al., 2004):

$$p_n = \frac{\langle B_n^2\rangle}{\langle B^2\rangle} = \frac{(n+1)\sum_{m=0}^{n}(c_n^m)^2}{\sum_{n'=1}^{N}(n'+1)\sum_{m=0}^{n'}(c_{n'}^m)^2}$$

and $(c_n^m)^2 = (g_n^m)^2 + (h_n^m)^2$; g^m_n , h^m_n are the Gauss coefficients of a spherical harmonic global model.

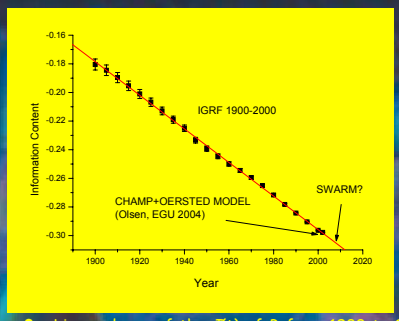

Figure 3. Linear decay of the *I*(t) of B from 1900 to 2000 from IGRF model. The most recent point at 2002 is from model by Olsen (2004) that used a selection of CHAMP and Oersted satellites magnetic data.

I(t) of B shows a scaling with timescale of 800 years. Also the information of the Secular variation shows the same scaling, denoting roughly the same order of timescale (420 years). For Hopital Theorem this happens during a geomagnetic reversal (De Santis et al, 2004). Future data from satellites (eg. SWARM) will test the linear behavior of I(t).

Persistence of vxB

rot(**vxB**) contributes to new secular vatiation. Let us consider south geomagnetic pole speed **v** and its corresponding field **B**. We can assume they are representative of the speed of the main magnetic (dipole) line and its magnitude.

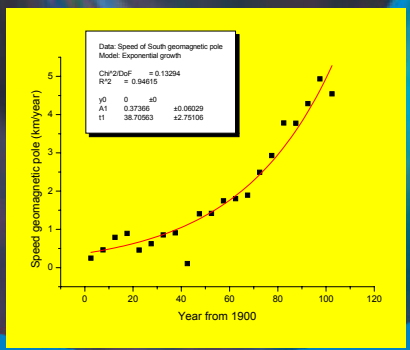

Figure 4. Exponential growth of the geomagnetic pole speed as given by IGRF from 1900 to 2005.

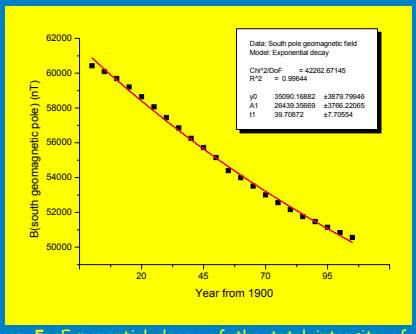

Figure 5. Exponential decay of the total intensity of the geomagnetic field (with respect the mean) in the south geomagnetic pole as given by IGRF from 1900 to 2000.

South Atlantic Anomaly

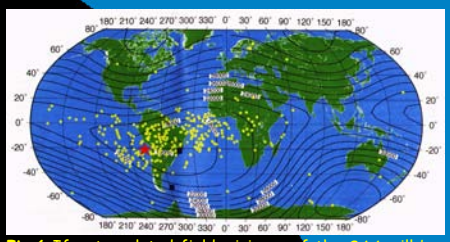

Fig.6 If extrapolated field minimum of the SAA will be zero by **240 years** (Heirtzler, 2002). Circles are failures of TOPEX (1340km altitude) for 1992-1998 (Heitzler et al., 2002).

SAA can be seen as the surficial manifestation of an emerging reverse magnetic flux in the outer core (e.g. Takahashi et al., 2005). Accurate satellite data as Swarm will provide better investigation about this point.

Other Arguments

Asymmetry between Southern Hemisphere (SH) and Northern Hemisphere: in terms of contributions to axial dipole moment (Gubbins, 1987) and of **VGP dispersion** (Opdjke & Meija, 2004), typical of reversals.

Reverse fluxes at CMB from satellite magnetic data (Hulot et al., 2002) and geodynamo symulations (Takahashi et al, 2005).

Increased magnetic storm activity (Clilverd et al., 1998)

Rapid decrease of total intensity at Antarctic stations (Rajaram et al., 2002)

Conclusions

- Time extrapolation of some quantities suggests a possible imminent geomagnetic reversal or excursion:

  $\langle B^2\rangle$ over the globe gives a '**dead field**' by **800-1000** years.

  In particular, shorter 'dead' times over SH:

  $\langle B^2\rangle$ for θ>150° gives a 'dead field' by **340 years**.
  |B| will be zero at the minimum of SAA (South Africa at that time) by **235 years**.

- Timescales of Information Content of **B** and **SV** are of the same order (**800 and 420 years)** as possible indication of an imminent reversal.

- Persistence of vxB for the last 100 years in the SH→ **Persistence of the present trend of the SV in SH.**

The possibility of an imminent geomagnetic polarity reversal or excursion cannot be discarded and merits the due attention.
High accuracy satellite data as from Swarm will allow to better verify this possibility.

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