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Mapping of the lithospheric magnetic field using CHAMP satellite data

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Abstract

In this work, we will present a mapping of the magnetic field generated by the heterogeneities of magnetization of the lithospheric rocks.

This field is so called the lithospheric field and it is the result of two contributions: the induced contribution and the remanent magnetization contribution. It therefore brings a crucial constraint on the magnetic properties of the crustal rocks. To map this field, we will use the scalar and vector data collected during CHAMP mission from July 15th, 2000 to September 19th, 2010. The sampling frequencies of 1 Hz at the average altitude of about 350 km of measurements allow us to obtain a high resolution mapping.

The method used to reduce the effect of the other contributions of the Earth magnetic field is based on the separation of the internal field using models of 16th degrees. These models were calculated for each of three months in order to move secular variations. The use of these algorithms has permitted to map the strong lithospheric magnetic anomalies of large wavelength using only raw satellite observations.

1. Introduction

The Earth's magnetic field measured at the surface or satellite is defined as the result of two major processes having their sources within the earth (the internal field) and outside of the latter (the external field), [Langel1993].

• The field internal origin (99%) induced by continuous movements of the liquid core, and magnetic rocks of the crust where temperatures are well below the Curie isotherm.

• The external field is generated by electric currents circulating in the ionosphere and magnetosphere. Although the external magnetic field is only 1% of the total field, this parasite component must be removed to determine the exact properties of the internal field. In this work we are interested on mapping the magnetic field of the lithosphere using magnetic scalar and vector data at low altitude of CHAMP satellite.

1.1 CHAMP Satellite

CHAMP (**CH**Allenging **M**inisatellite **P**ayload) was launched on July, 15th 2000 from the Russian cosmodrome "Plesetsk" into a near polar circular orbit of ~87.3 ° inclination and an altitude of about 450 km for the first four years to reach an average of 320 km. This mission has generated simultaneously highly precise gravity and magnetic field measurements over a 10 years period [Maus 2007].

The CHAMP satellite was equipped with a proton Overhauser magnetometer and a tri-axial fluxgate providing for the first time a thin cover at low altitude with high precision of a global mapping of the magnetic field in an optimal spatial resolution latitudes and 7 ° of longitude [Lemouël et al 2003].

2. DATA selection

The main objective of this work is to obtain measurements of the internal geomagnetic field origin. Thus, data processing focuses on (Figure 1):

-Decoding and processing scalar and vector data in the local location.

-Reduce the effect of the external magnetic field (Figure 3) by selecting the data at low altitudes linked to the night hemisphere (between 22h and 06h). These selected data are compared with geomagnetic index.

In our case we used the measures corresponding to a planetary index Kp <= 2 + and an index Dst <= 15nT [Mandea and Langlais 2002].

Several tests were executed in order to find the most optimal coverage data corresponding to the shortest possible duration (Figure 2). More the period is shorter, the effect of the external field and the induced magnetization are reduced.

The data selected by the method described above allowed us to establish global models of three months in spherical harmonics of the internal field. This method also minimizes the effect of the secular variation.

Finally, the lithospheric field is determined by calculating the residuals between the selected field and the model field. We show an example of the lithospheric field established from data 2009-2010.

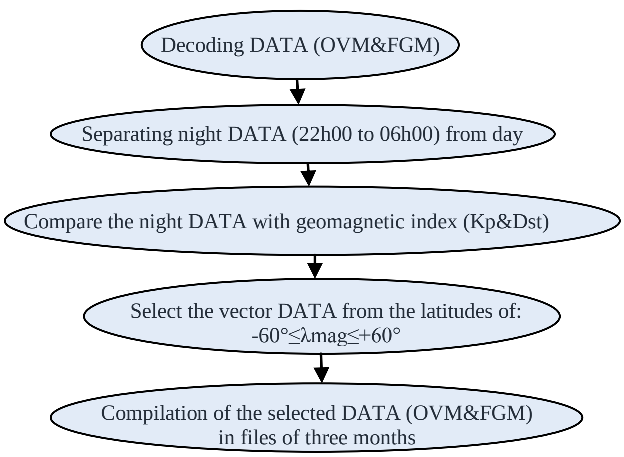
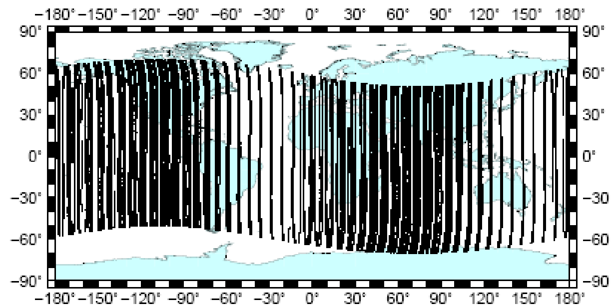


Figure 1: Algorithm used to select magnetic data from CHAMP measurements.

(a)



(b)

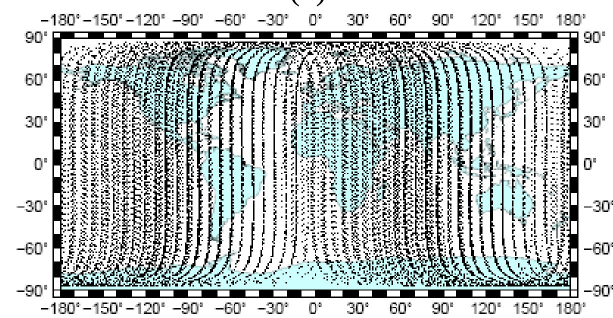


Figure 2: Example of geographic distribution using in inversion: (a) magnetic scalar (b) vector data, selected for $kp \le 2+, |Dst| \le 15$ for the 1st quarter of 2007

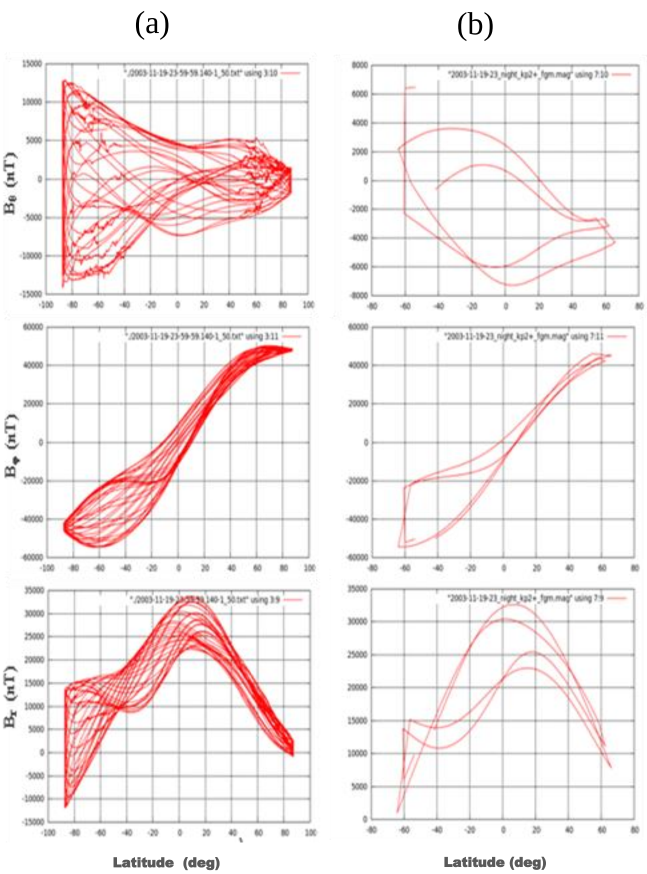


Figure 3: Variation of raw vector geomagnetic components (a) and selected (b), for the day of 19-11-2003

5-Modeling methodologie

- Objective of the inversion:

$$\sigma^{\mathbf{2}} = \sum_{n=\mathbf{1}}^{Nobs} (\vec{B}^{obs}(r,\theta,\varphi,t) - \vec{B}^{\mathrm{mod}}(r,\theta,\varphi,t))^{\mathbf{2}} \qquad (1)$$

- The model in this algorithm is based on the following equations:

$$B^{\mathrm{mod}} = -\nabla V \qquad (2)$$

- On the surface of the Earth, similar to a sphere of radius a ≈ 6371.2 km, the scalar potential V can be written [Lemouël, 1976] in the form of a spherical harmonic expansion as follows:

$$V(r,\theta,\varphi,t) = V_{\mathrm{int}}(r,\theta,\varphi,t) + V_{ext}(r,\theta,\varphi,t) \quad (3)$$

$$V_{\mathrm{int}}(r,\theta,\varphi,t) = a\sum_{n=\mathbf{1}}^{\infty}\sum_{m=\mathbf{1}}^{n}\left(\frac{a}{r}\right)^{n+\mathbf{1}} (g_n^m(t)\cos m\varphi + h_n^m(t)\sin m\varphi)P_n^m(\cos\theta) \qquad (4)$$

$$V_{ext}(r,\theta,\varphi,t) = a\sum_{n=\mathbf{1}}^{\infty}\sum_{m=\mathbf{1}}^{n}\left(\frac{r}{a}\right)^{n+\mathbf{1}} (q_n^m(t)\cos m\varphi + s_n^m(t)\sin m\varphi)P_n^m(\cos\theta) \qquad (5)$$

6. Summary and Conclusions

- The data selection method used was not very efficient to moving the effect induced field and the external field remains important. We will use these selection criteria in GSM coordinate system. This system is so used to determine magnetospheric corrections which are not eliminate on residual components.

- In our mapping (Figure 4) the Bangui's anomaly is showed very clearly in each component.

- The anomalies associated to the West African craton, although identifiable but also strongly affected by residual external fields.

Altitude and spatial resolution make mapping of crustal field more difficult, which requires integration of other complementary data such as terrestrial and aeromagnetic measurements.

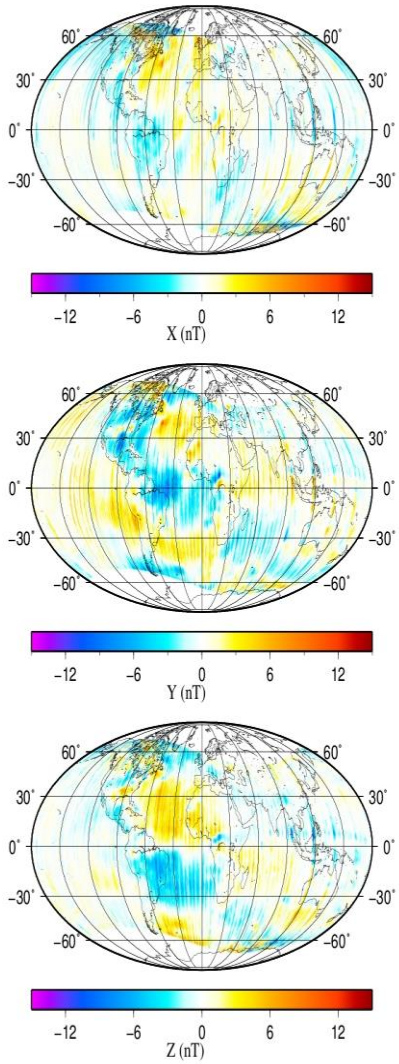


Figure 4: Residual Magnetic Field components obtained from the difference of a model of degree 16 for the years 2009-2010 with the observations of CHAMP for $Kp \leq 2+$and $| Dst | \leq 15$.
(Mollweide projection, centered longitude 0 ° color scale in nT)

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