Data Analysis of São Martinho da Serra Observatory, Brazil.

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Abstract

Brazil is located in a strategic geomagnetic area due to the presence of the South Atlantic Magnetic Anomaly (SAMA) and due to the equatorial electrojet. In this paper, we present the plans of the National Observatory for the next magnetic observatories that will be instalated in Brazil. We analyzed and compared the data generated in São Martinho da Serra (SMS) Observatory (Rio Grande do Sul), since 2001, with two global models. A traditional data processing and wavelet analysis was applied.

Introduction

Historically the knowledge of the morphology and variability of the magnetic field is important for understanding the processes occurring in the ionosphere, including radio transmission and for obtain information about the Earth interior.

The magnetic field of the Earth varies in space and time, with contribution of the internal and external fields. It is observed in a wide range of periods: from milliseconds to millions of years (Figure 1). For example, the geomagnetic reversals occur in longer time scales of millions of years while the solar storms may occur during few days. In this paper we are mainly interested in analysing time scales from days to the secular variation generated in the core, in scales of few years.

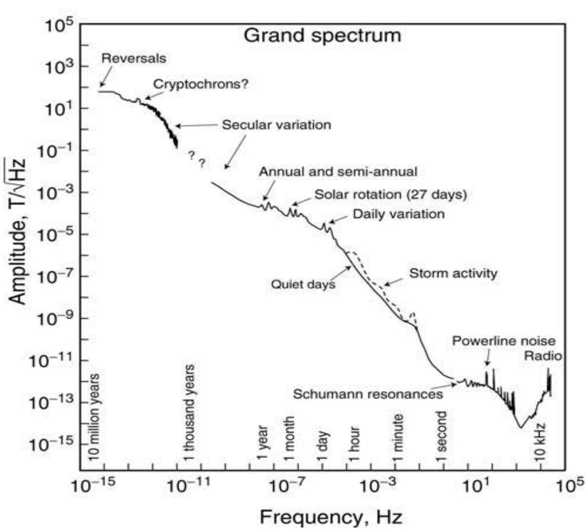

Figure 1. Frequency variation of the magnetic field, showing the different sources. (Constable and Constable, 2004).

The geomagnetic field can be observed by satellites, terrestrial, aerial and maritime surveys, and by magnetic observatories that provide the more precise and continuous measurements of the magnetic field at the Earth´s surface. Global models of the magnetic field use this variety of data.

In this paper, we use two global models to compare with the data of SMS Observatory: the first is the IGRF (International Geomagnetic Reference Field, Maus, S., *et al*, 2003) and the second the CM4 model (Sabaka T.J., *et al*, 2004). Both are spherical harmonic models developed to describe the geomagnetic field anywhere in the globe. The difference between these two models is that the IGRF can forecast the core magnetic field for the next five years while the CM4 is a comprehensive model able to separate the different sources of the magnetic field (core, magnetospheric and ionospheric) from 1960 until 2002. Both models use data from satellites, stations, and INTERMAGNET (International Real–Time Magnetic Observatory Network) observatories.

INTERMAGNET is a global net of observatories monitoring the Earth magnetic field. They provide patterns for the measurements and equipments, facilitate the exchange of data and make data available in near real-time. Their staff helps on the installation of new magnetic observatories around the globe. Currently there are 118 observatories connected to INTERMAGNET (Figure 2), where it is clear the uneven spatial distribution, with most observatories concentrated in Europe and only few in South America.

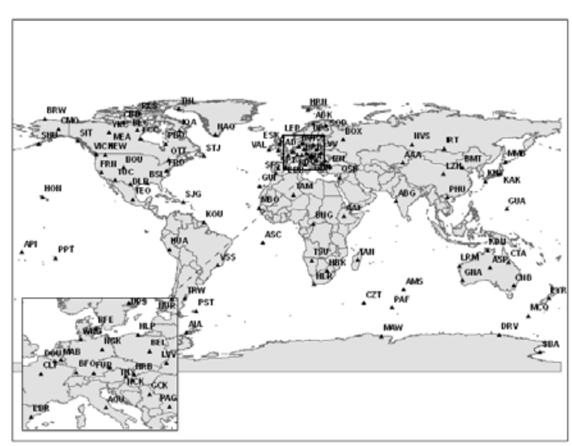

Figure 2. Spatial distribution of INTERMAGNET observatories (Intermagnet.org).

São Martinho da Serra (SMS) Observatory and Planning of new Magnetic Observatories in Brazil

In Brazil there are three magnetic observatories: the first in Vassouras (Rio de Janeiro) that works since 1915 and is part of INTERMAGNET; the Tatuoca Observatory (Pará) that started in 1957 but with many interruptions and São Martinho da Serra (SMS) in the South of Brazil that started in December, 1996.

SMS observatory is located 20 km from the northwest of Santa Maria cite in Rio Grande do Sul (Latitude -22,4, Longitude -43,65, Altitude of 470m). It was built by the University of Santa Maria in collaboration with the National Institute of Spatial Research. The general structure of the SMS observatory is showed in Figure 3.

Observatories have two kids of measurements placed in two different houses: the first is the variometer house where the components of the vector magnetic field are measured continuously in arbitrary units; and the second house is for absolute measurements in terms of physical basic units or physical constants. The instruments usually used for the absolute measurements are the proton magnetometer that measures the total field (F) and the Fluxgate Theodolite (DI-Flux) to measure the declination and inclination angles. The instrument commonly used for the continuous measurements are the Fluxgates.

All three Brazilian observatories measure continuosly the horizontal (H) and vertical (Z) components and the declination angle (D). They use Ukrainian magnetometers Korepanov with high resolution and registering data each second. Tatuoca Observatory is using this instrument since June 2008, Vassouras since February 2009 and São Martinho da Serra since November 2009, with some interruption in January, 2010. The problem in SMS observatory is the absence of constant measurements of the absolute values of total field and the angles of declination and inclination. This causes problems to construct the base lines. There are some few measurements of F showed In this work.

The National Observatory is planning to install 7 new observatories in Brazil: two locations are already decided that are Pantanal in Mato Grosso and one in Amazon. The installation of the observatory in Pantanal is part of a cooperation Project between the Brazilian National Observatory and GFZ- Potsdam (Germany). There are also many new stations already working in the Electrojet region and planned for the South of Brazil (Figure 3).

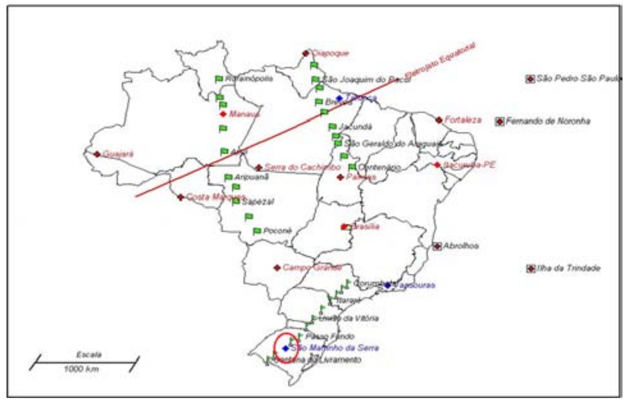

Figure 3. Map representing the location of SMS observatory by the red circle, the location of current working observatories (in blue) and the magnetic stations (in green). The future Pantanal and Amazon Observatories are represented by a yellow square.

Method

The first part of this work was dedicated to the pre-processing of data. We first join all the data available in one single file, accounting for the many gaps found from 2001 until 2010. The second step was to exclude outliers from the data, we eliminated values of H smaller than 19300 nT and larger than 18600 nT and also correct some shifts present in the data. We followed to calculated daily means, from the 2 seconds data that were available, in order to observe quiet-days and solar storms. We only considered days with more than 12 hours. We also aim to analyse the secular variation, and for that we calculated monthly means including only the months with more than 15 days.

After the pre-processing we were able to analyse daily and the secular variations. We compared the long period data with two different models: IGRF and CM4. In both models we calculated the H component for the period of SMS functioning.

We used the wavelet analysis in order to filter different frequencies of the long-period time variation of the magnetic field. A wavelet is a waveform of limited duration that has an average value of zero and tends to be irregular and asymmetric. Its main property is the dilation, which is the variation of the wavelet scale: the larger the scale, the lower the frequency analysed.

The advantage of using wavelet is that it is possible to investigate both the global (low frequency) and the detail (high frequency) of the signal by stretching and squeezing the wavelet while sliding it along the signal. In contrast to Fourier analysis, it is possible to detect localized time features of the signal.

Results and Discussion

In this paper we only used the H components since the declination and the vertical component showed very noisy values and with a great departure from the model IGRF.

The amount of data available for each year is showed in the histogram of Figure 4, where one can check that 70% of the years have more than 250 days completed. For this work, there was no data available after June, 2010.

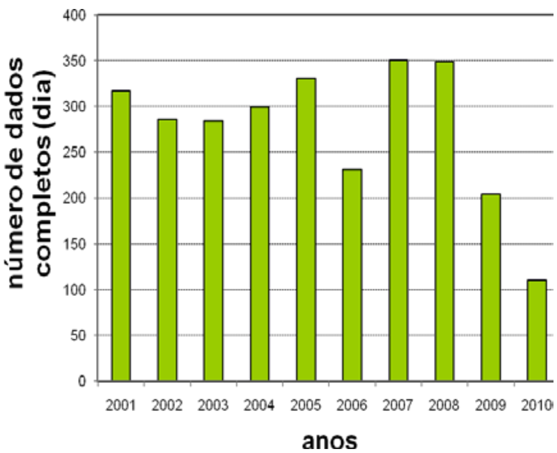

Figure 4. Histogram showing the data available per year, for SMS observatory.

We analyse two temporal scales: diurnal and annual variations. The diurnal variation occurs due to interaction between the Earth internal magnetic field and the solar plasma. We show one example of a quiet day variation in SMS observatory.

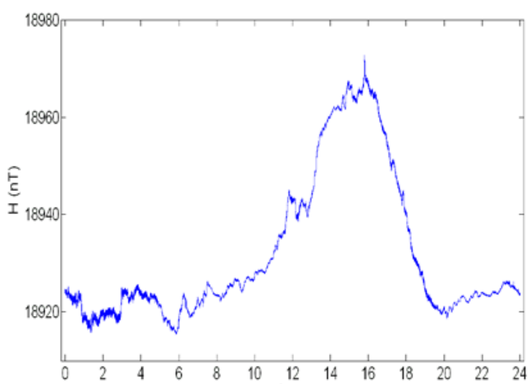

Figure 5. Example of a geomagnetic quiet-day measured in SMS observatory on the 4th October, 2003.

Solar storms are magnetic events where the solar wind transfers energy to the interior of the Earth magnetosphere. The main characteristic of a solar storm is a decrease of the horizontal component (H) followed by a recovery phase (Kamide *et al.*, 1998). The most well know effects are the intensification of electric currents in the magnetosphere and at the Earth´s surface that may cause problems in satellites and in the GPS systems (Savian *et al*.,2005). Figure 5 shows one example of solar storm registered in SMS observatory. This storm occurred on the 28th October of 2003 and it was measured in the horizontal component (H). By comparing the scales on the figures 5 and 6, in the quiet day the variation range was about 60 nT while in the disturbed day it was approximated 10 times bigger.

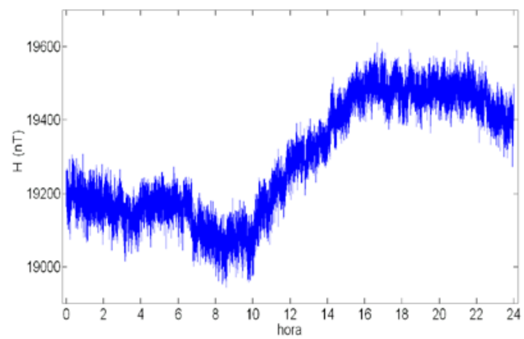

Figure 6. Example of a geomagnetic storm in SMS observatory, on the 28th October, 2003.

We analysed the long time period data by the monthly mean values, from 2001 to June of 2010, as showed in Figure 7. The IGRF values of H for SMS location were also calculated and plotted in Figure 7. There is a decreasing difference, between the SMS data and IGRF calculation, as the time increases. In 2010, for example, this difference is insignificant. These differences are even larger when comparing with the absolute measurements performed by the National Observatory during 4 different days.

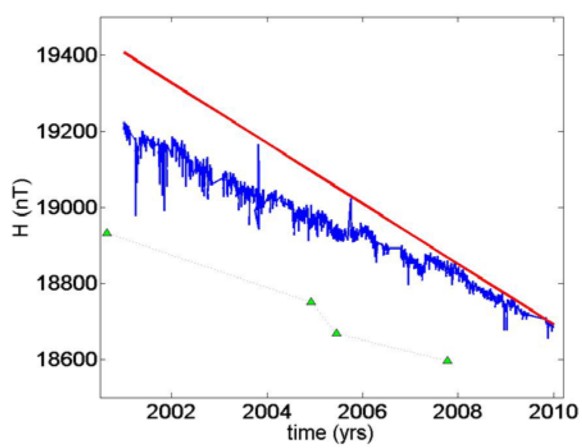

Figure 7. Monthly means of the horizontal magnetic component from SMS observatory registered from 2001 to 2010 (in blue), the calculation of the IGRF model for the same epoch (in red) and the absolute measurements of H (green triangles).

We also calculated the CM4 core contribution for the X and Y components since 1969 until 2002 (Figure 8). There is a great different from this model to the data registered in SMS observatory.

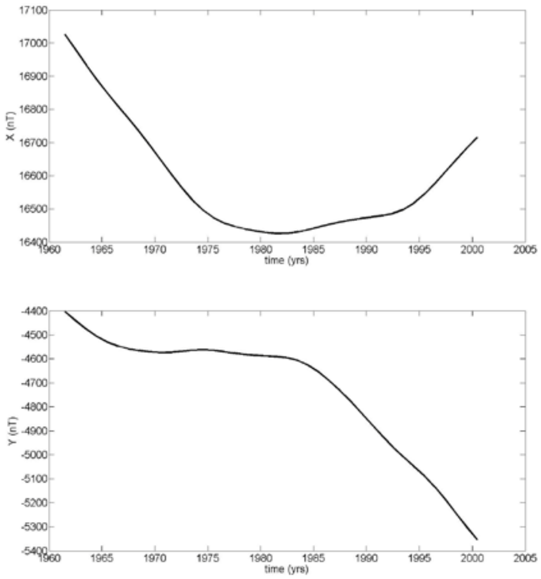

Figure 8. Calculations of X (top) and Y (bottom) component of the magnetic field using CM4 model for the location correspondent to SMS observatory.

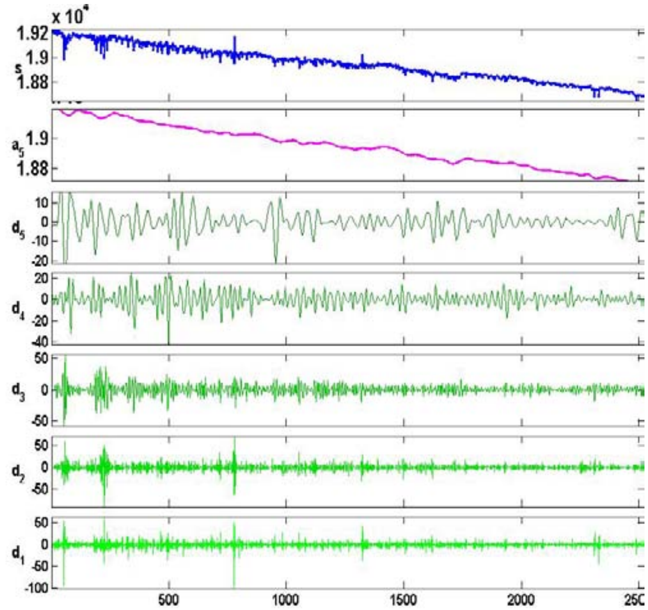

Figure 9. Wavelet decomposition at level 5 using Coiflet wavelet: s = a5 + d5 + d4 + d3 + d2 + d1 .

It is important to notice that the IGRF only considers the internal magnetic field and it is calculated for each year while the data is in monthly means and includes the influence of external fields. During this time period of SMS observatory, the IGRF calculation was mostly based on observatories and did not include SMS in their calculations. This means that the model is not well constrain in this region, what may explain the discrepancy between both.

In Figure 7, one may notice that there are still some spikes and noise to be removed. If we want to analyse only the internal core contribution of the magnetic field we need to remove the external shorter period influence from the data.

In this paper, we propose to filter this data using wavelet analysis, where it is possible to filter the spikes and high frequency noise contained in the data. Figure 9 shows one example with SMS data, using Coiflet wavelet and decomposing the data into level 5. Most spikes and high frequency signal is on the “d” decomposition (graphs in green in Figure 9) and the low frequency generated in the core is concentrated on the “a” part of the decomposition.

The next steps of this work will be to calculate the secular variation using the low frequency signal obtained from the wavelet analysis and observe whether it is possible to detect the local jerks reported for 2003 and 2005.

Acknowledgments

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