One century of data from Vassouras Magnetic Observatory (1915-2015)

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Introduction

Vassouras Magnetic Observatory (VSS) was the first observatory in Brazil, starting its measurements in 1915. VSS plays an important role in monitoring of the magnetic field in the south hemisphere mainly because it is located in region of Southern Atlantic Magnetic Anomaly (SAMA), in addition, due to its high data quality and real-time transmission VSS is part of the INTERMAGNET (since 1999) network, contributing to global geomagnetic model development.

This work presents the history of VSS as well as the centennial dataset (1915-2015). We explore the comparison of VSS data and results of IGRF model. Solar-quiet (Sq) and storm day are presented to evaluate the influence of the exernal field on VSS as well as the possible occurrences of the jerks evidencing the main characteristics of the secular variation.

Theorical Fundamentals

- **Relation between the elements of the geomagnetic field**

$$F^2 = X^2 + Y^2 + Z^2, \qquad H^2 = X^2 + Y^2,$$
$$X = Hcos(D), \quad Y = Hsen(D) \quad and \quad Z = Fsen(I)$$

- **Secular variation**

The secular variation is the sucessive difference of the values of field components given by:

$$\frac{dX}{dt} = X(t+1) - X(t)$$

where t represents time in years.

- **Fit by spline interpolation**

The secular variation of X,Y and Z compontents were fitted using an algorithm of linear fit by spline method:

$$f(x) = f(x_{n-1}) + t_{n-1}(x - x_{n-1}),$$

for $x_{n-1} \leq x \leq x_n$

- **Root Means Square (RMS)**

We calculated the erroe between the model IGRF and the data from VSS using RMS:

$$e_{RMS} = \frac{1}{N}\sqrt{\sum_{i=1}^{N}(VSS_i - IGRF_i)^2},$$

the RMS can be view in the Table 1.

Geomagnetic Field Elements

In the figures (1 to 7) below are present the evolution of the main field components over the last 100 years for VSS and IGRF12 model. From 1915 to 1999 the annual means data were given directly by VSS, from 1999 to 2015 were performed annual means using the minute data of components from INTERMAGNET. The RMS error between VSS and IGRF can be seen in Table 1. Table 2 shows the rates of change of the Earth's magnetic field for VSS and IGRF model over the last 100 years.

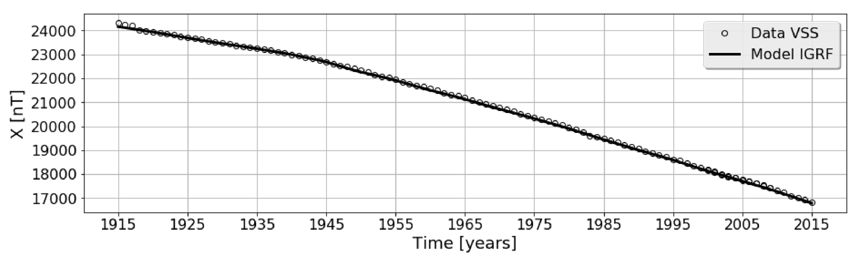

Figure: 1. Annual means: X component

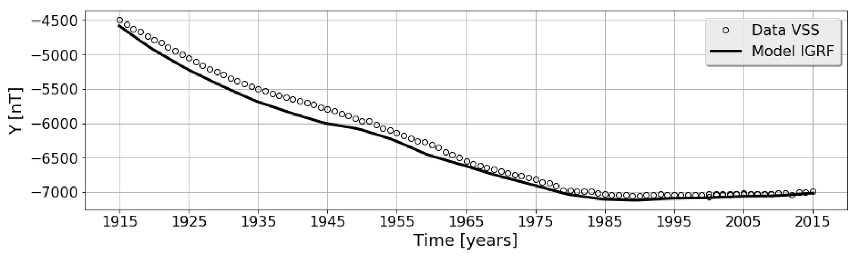

Figure: 2. Annual means: Y component

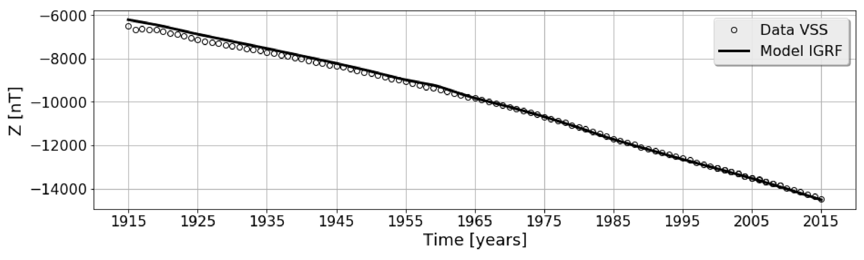

Figure: 3. Annual means: Z component

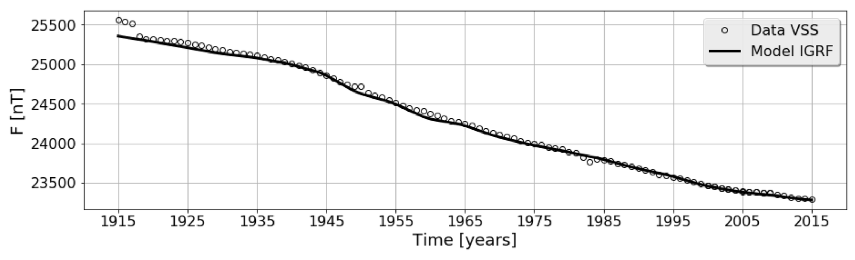

Figure: 4. Annual means: F component

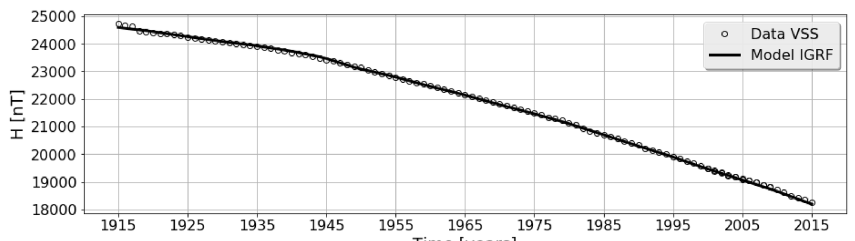

Figure: 5. Annual means: H component

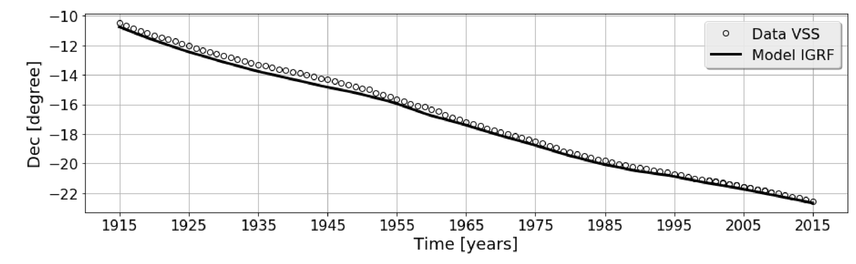

Figure: 6. Annual means: D component

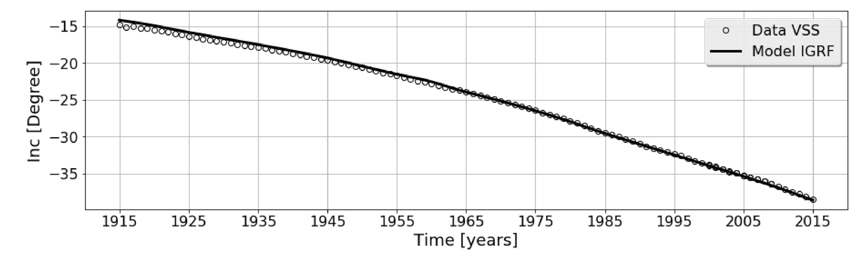

Figure: 7. Annual means: I component

Elements	e_{RMS}
X Component	5.23
Y Component	12.45
Z Component	12.67
Total field F	4.62
H	3.71
Inclination	0.03
Declination	0.03

Table: 1. RMS error of the measurements of VSS and IGRF model for the 100 years of data.

Change/year			
Comp	VSS	IGRF12	WMM2015
F (nT)	-18.0	-5.2	-9.9
X (nT)	-82.7	-91.6	-93.3
Y (nT)	28.0	2.2	5.4
Z (nT)	-86.0	-98.0	-94.1
H (nT)	-68.0	-85.5	-88.3
I	−0°14′13″	−0°19′15″	−0°19′4″
D	−0°7′12″	−0°6′15″	−0°5′49″

Table: 2. Change rate for the main field components over 100 years.

History (1915 - 2015)

In 1913 the engineer and director of the Observatório Nacional (ON), Henrique Charles Morize in partnership with the astronomer Alix Correa Lemos idealized the city of Vassouras, RJ (Latitude 22.4° S and 43.35° W) as the ideal place for installation of the VSS. The old place at Morro do Castelo where the Imperial Observatório do Rio de Janeiro (IORJ) was located had a high level of magnetic noise, this problem affected the measurements of the Earth's magnetic field and was the reason for the change of the magnetic observatory from Rio de Janeiro to the Paraíba Valley.

Sq and Storm Days

The Figure 8 shows the total field (VSS) for a day with high solar activity, it is observed that near october 30, 2003 (blue line) we had a Sq and from there we observed the magnetic storm (red line):

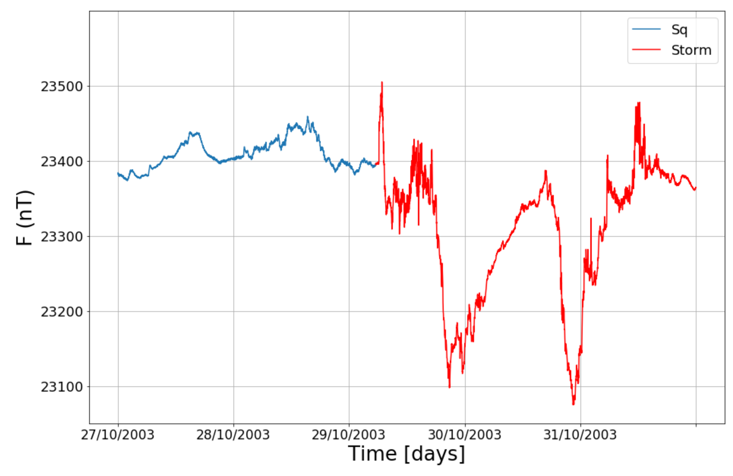

Figure: 8. Storm occurred on October 30, 2003.

Geomagnetics Jerks

For possibles occurence of jerks we can analyze first the X, Y and Z components using Least Square (LS) to fit trends:

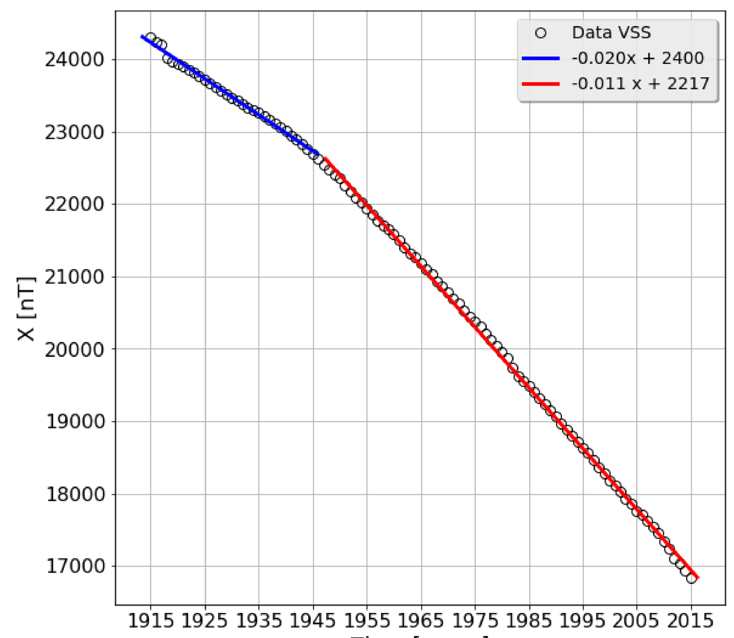

Figure: 9.For component X, two straight were fitted, showing a trend change and a possible jerk in 1947

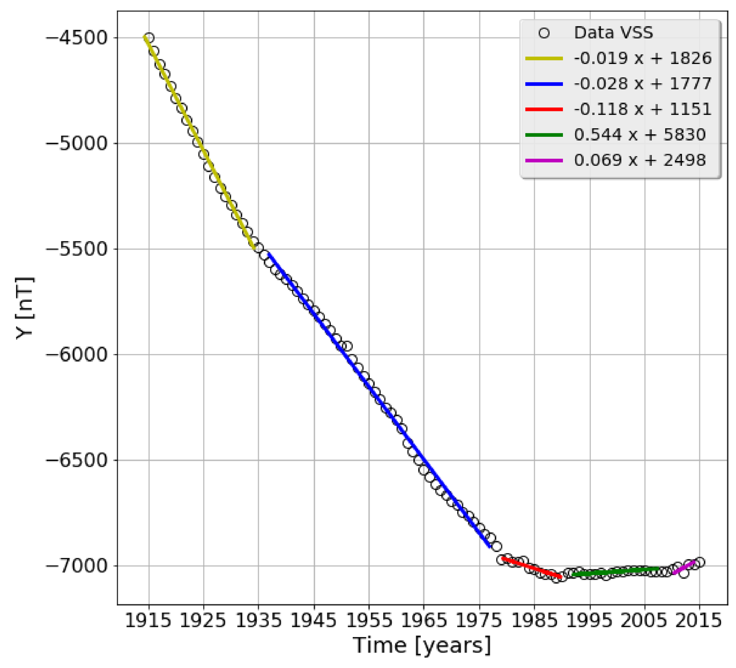

Figure: 10. Possibles jerks occurences in 1937, 1978, 1990 and 2013

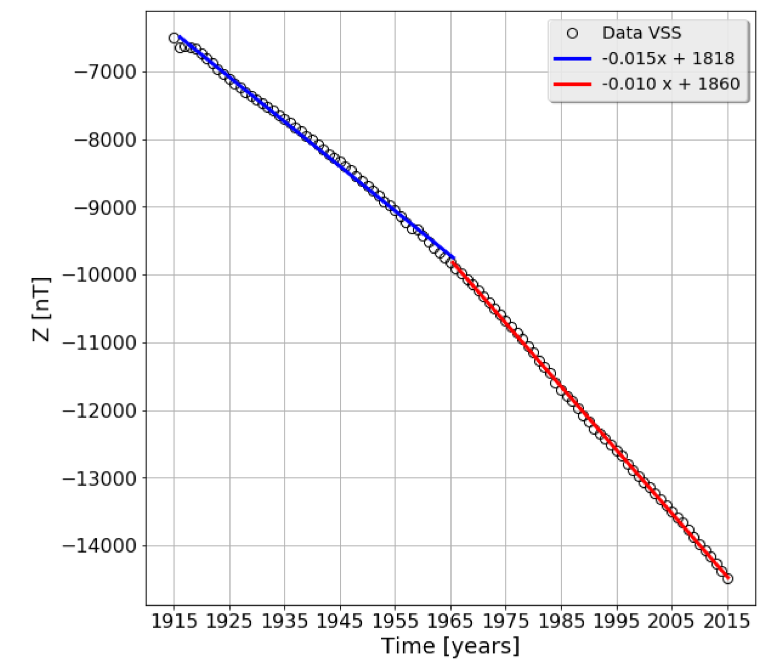

Figure: 11. Possible jerk occurence in 1965

VSS

Figure: 12. Entrance gate of the Vassouras Magnetic Observatory.

VSS

Period — Instruments

1915 - 1982 — Ruska Observatory Pattern (Declination), QHM 534 (Horizontal component) and Earth Inductor Toepfer (Inclination) Variometer unifilar Toepfer.

1982 - 2012 — DI-flux Bartington, MAG-01 with theodolite Zeiss 010 (1") (Declination and Inclination), PPM Geometrics 816 (Total intensity F).

2012 - 2014 — Variometer fluxgate of INTERMAGNET.

Geomagnetic Jerks

Secular variation is widely used to indicate fast changes with time of the main field that are probably due to the changing pattern of core flow. We can analyze the secular variations (dX/dt, dY/dt and dZ/dt) by spline and we suggest possible jerks (see figures' caption below):

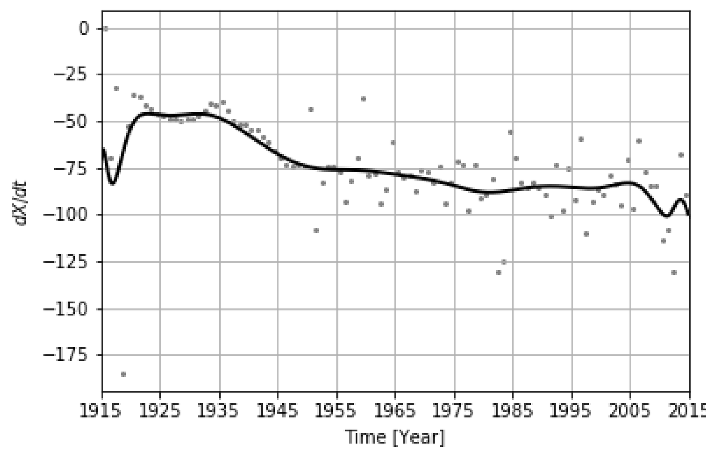

Figure: 13. Secular variation to X component, possibles jerks: 1935, 1947, 1980, 2005 and 2013

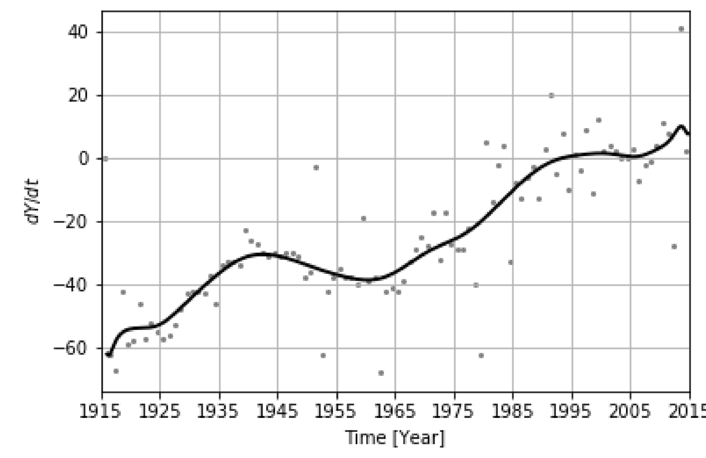

Figure: 14. Secular variation to Y component, possibles jerks: 1925, 1940, 1960, 1980, 1993 and 2007

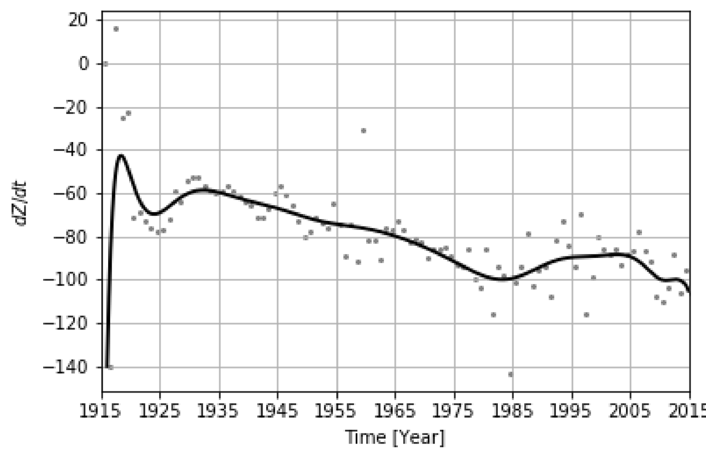

Figure: 15. Secular variation to Z component, possibles jerks: 1925, 1932, 1983, 2005 and 2013

References

- Observatório magnético de Vassouras: 100 anos de pesquisas e serviçoes prestados à ciências. (2015) Observatório Nacional, Rio de janeiro.
- http://www.intermagnet.org
- https://www.ngdc.noaa.gov