Brazilian geomagnetic observatories: recent improvements and data availability

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Abstract

There are two geomagnetic observatories in Brazil: Vassouras (VSS), in Rio de Janeiro, operating since 1915 and Tatuoca (TTB) close to Belém in Pará, operating since 1957. Data from these observatories are used in a variety of studies concerning the internal and external geomagnetic fields, and in geomagnetic field modeling. They are also valuable for commercial activities, such as in geophysical surveys or well bore surveying during horizontal drilling. In this work we summarize the recent improvements made in VSS and TTB, through an international cooperation between Observatório Nacional, the German Research Centre for Geosciences and Universidade Federal do Pará. The observatories were modernized to provide data of highest quality and to guarantee continuous operations.

Introduction

The geomagnetic field results from the superposition of magnetic signals that differ in their origin. The various field sources are the slowly changing electric currents in the Earth's core, magnetisation of the lithosphere, variable electric currents in near-Earth space (magnetospheric and ionospheric contribution) and the corresponding electric currents induced in the Earth's mantle and oceans. In this context, geomagnetic observatories are an important tool to sample and further study the magnetic fields and associated processes, as they provide calibrated vector data in an absolute reference frame (Matzka et al., 2010).

Aside from being an important part of the relatively small number of observatories operating in the South American region (see Figure 1 map), Vassouras (VSS) and Tatuoca (TTB) observatories data can be useful in space weather monitoring, directional drilling activities (Buchanan et al., 2013), geophysical surveys data processing (e.g. temporal reduction) and in scientific investigations. Their low-latitude (VSS) and equatorial (TTB) locations, close to the coast and in the vicinity of the prime Brazilian oil fields, makes these observatories especially valuable for commercial purposes. Scientifically, they sample interesting features of Earth's magnetic field such as the South Atlantic Anomaly (SAA, region with the lowest field strengths), the equatorial electrojet (EEJ, ionospheric current confined to the magnetic equator region, i.e. the line around the globe where the field is horizontal) and geomagnetic storms.

In order to modernize and operate VSS and TTB, the Observatório Nacional (ON, Brazil) and the German Research Centre for Geosciences (GFZ, Germany) started a cooperation in 2012.

Vassouras geomagnetic observatory

The centennial Vassouras geomagnetic observatory (see Figure 1 red circle and panel D for VSS absolute hut) is located in the city of Vassouras, Rio de Janeiro state, Brazil (22.24°S, 43.39°W). Since 1999 it is part of INTERMAGNET (International Real-time Magnetic Observatory Network), following its standards of measurements and recording the geomagnetic field. VSS is located close to the center of the SAA region. Its records of the SAA intensity variation and temporal evolution are important for theoretical studies (concerning the flow patterns in the Earth's core that produces the SAA) and practical studies such as the effects of strong radiation on satellites in this region.

VSS was modernized with two DTU FGE vector magnetometers and two overhauser scalar magnetometers that are used to continuously measure the Earth's magnetic field (see Figure 1 panel E). The first FGE was installed in September 2014 and the second (backup system) was installed in November 2017. Data is transmitted in real time through mobile telecommunication network. There is a backup internet connection in case one of them fails. Training on absolute measurements are regularly done with VSS technicians. The measurements are systematically quality-checked and feedback is provided to VSS staff.

Tatuoca geomagnetic observatory

The Tatuoca geomagnetic observatory is in operation for more than 60 years at the small island (230 m x 460 m) of Tatuoca (see Figure 1 blue circle and island picture in panel A), located in the Amazon River, in Belém (Pará state), Brazil (1.20°S, 48.51°W). Although there is an extensive time series of TTB data, it was never a member of INTERMAGNET.

The importance of TTB data is highlighted by the position of Tatuoca near both magnetic and geographic equator, as well as the proximity to the SAA. In addition, although TTB was installed in 1957, it only became an equatorial station in the last decade due to the strong secular

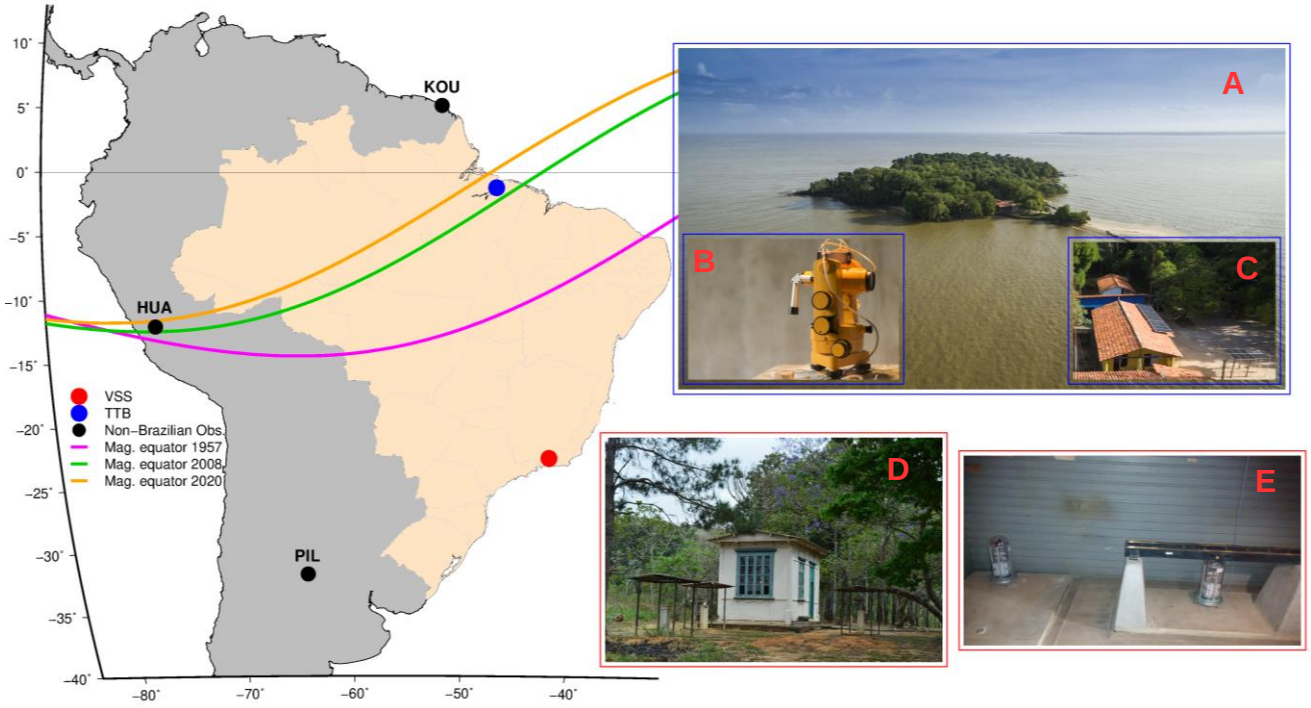

Figure 1 - Map with the Brazilian observatories (VSS as red circle, TTB as blue circle), other South American observatories (black circles: KOU, HUA and PIL) and the position of the magnetic equator line for the years of 1957 (magenta), 2008 (green) and 2020 (orange), as predicted by the IGRF-12 model. Pictures with blue border indicates Tatuoca Island (panel A, where TTB is installed), TTB ZEISS theodolite attached to a fluxgate magnetometer and a GEOMAG zenith ocular for absolute measurements (panel B), and 12 new solar panels at TTB office roof (panel C). Pictures with red border indicate VSS absolute hut (panel D) and its two DTU FGE variometers (panel E).

variation of the inclination angle in the Brazilian longitudinal sector, leading to a fast movement of the magnetic equator (as shown in Figure 1 map by the equator position in different epochs calculated by the IGRF-12 model: 1957 in magenta, 2008 in green and 2020 in orange). Despite the scientific interest in the equatorial electrojet, currently the only INTERMAGNET geomagnetic observatory from the magnetic equator region is Huancayo (HUA) in Peru (shown in Figure 1 map).

With the aim to include TTB in INTERMAGNET, ON, GFZ and Universidade Federal do Pará cooperate since 2015 to fulfill the necessary requirements like high quality data, stable baselines, stable power supply and real-time data provision. As in VSS, continuous training and feedback concerning the operations are provided to TTB staff.

Concerning data acquisition and transmission, a new DTU FGE variometer (Figure 2) attached to a low-power data acquisition system, a new model G fluxgate magnetometer attached to a Zeiss theodolite for absolute measurements, a new laptop for data storage and transmission (Figure 3) and a 3G router for internet (Figure 3) were installed during the first visit to the island in 2015.

To guarantee a stable energy supply, a hybrid power system was installed in late 2017, aiming to avoid power outages and, hence, data gaps. This system comprises twelve new 265W solar panels (four for observatory operation and eight for staff's demand, see Figure 1 panel C), twelve new 200 Ah batteries, one new automatically starting generator and one equipment that allows remote management of power supply (Easysolar, see Figure 3) through internet. In this occasion, a backup 3G router for internet was also installed.

In 2018, a new GEOMAG-02M variometer was installed as a backup system (Figure 2) and a new GEOMAG zenith ocular for absolute measurements in equatorial regions was attached to a ZEISS theodolite (Figure 1 panel B). Another Easysolar unit was established for energy management regarding TTB staff's demand.

Figure 2 – TTB new variometers: DTU FGE (left) and GEOMAG-02M (right) sensors.

Figure 3 – New laptop (A), 3G router for internet (B) and energy management equipment (C) in TTB office.

Data processing and usage examples

The continuous records of VSS and TTB variometers are processed regularly. Data processing tasks include the check and correction of eventual noise or spikes in the time series, but also include baselines calculation and their further application. Baselines are calculated from the absolute observations and added to the variation data to obtain the absolute values of the field. Training activities on data processing are also periodically scheduled with VSS and TTB staff.

Both VSS and TTB data can precisely indicate the occurrence and intensity of geomagnetic storms in their respective locations. Storms are a problem for geophysical magnetic surveys and their disturbances need to be monitored and avoided. Figure 4 shows an example of a transition between quiet to disturbed periods in VSS records (F, D and I components) from July 2017, when a geomagnetic storm clearly starts to develop during July 16th.

Another possible use of the Brazilian observatories data is on the temporal reduction of geophysical surveys data. TTB, in particular, is useful for equatorial region surveys: in this area there is a more pronounced day-to-day variability and latitudinal gradient of the H component daily range, both due to the presence of the EEJ current. Estimating these effects is important for a reasonable survey data treatment. Figure 5 shows an example of TTB records from 2008, where the day-to-day variability of the H component daily range is observed for a period of six days, including a difference of almost 100 nT between two consecutive days (August 31st and September 1st).

Data availability

VSS and TTB data are free for scientific purposes: VSS data can be downloaded from INTERMAGNET website (http://www.intermagnet.org/), from the World Data Centre (WDC) for Geomagnetism in Edinburgh (http://www.wdc.bgs.ac.uk/) or directly requested to the authors; TTB data is partly available on the WDC website or can be directly requested to the authors. For non-scientific purposes, both VSS and TTB data need to be directly requested to the authors.

Conclusions and future work

Both Brazilian geomagnetic observatories were modernized by an international cooperation between ON and GFZ. VSS and TTB are now equipped with proper infrastructure, power supply, modern instruments and technologies used in observatories that are part of the INTERMAGNET network in the world. Quality control of observatory practice guarantee that high quality VSS and TTB data are being produced and available in real time for both scientific and commercial use.

As a result of the improvements made in TTB, an INTERMAGNET application was made in February 2019.

Acknowledgments

-Observatório Nacional, MCTIC, Brazil.

-GFZ German Research Centre for Geosciences, Germany.

-Universidade Federal do Pará (UFPA), MEC, Brazil.

-GBS thanks Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, grant 1799579).

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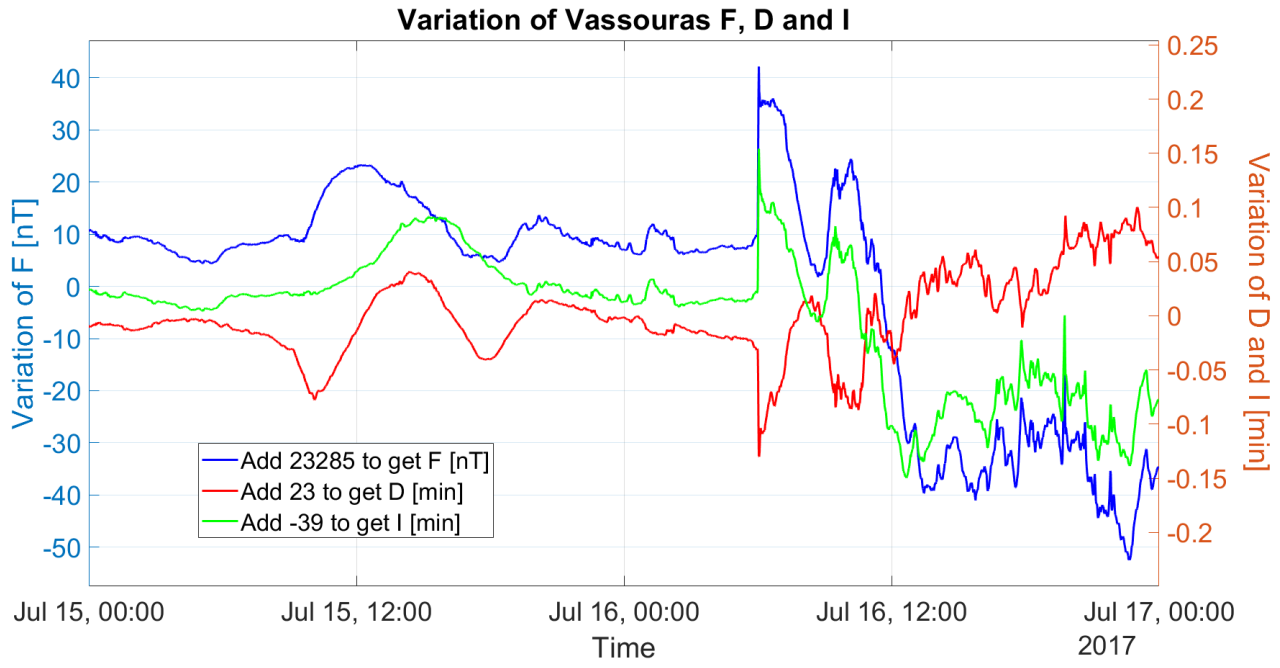

Figure 4 – Geomagnetic storm effects in VSS F (blue, in nanotesla), D (red, in minutes) and I (green, in minutes) components records.

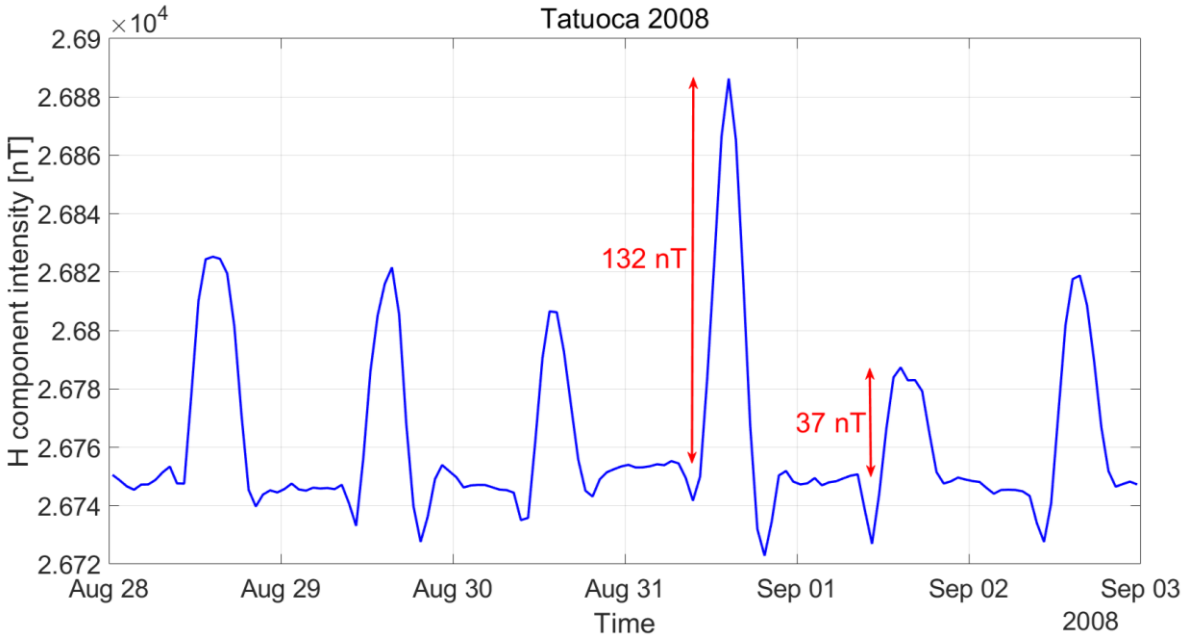

Figure 5 – Day-to-day variability in TTB H component records: an example of six days from August-September 2008. Distinct diurnal variations of August 31st (132 nT) and September 1st (37 nT) are highlighted in red.