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Effects of magnetic fields produced by simulated and real geomagnetic storms on rats

J.L. Martínez-Bretón [a,*], B. Mendoza [b,1]

[a] Posgrado en Ciencias de la Tierra, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D.F., Mexico
[b] Instituto de Geofísica, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 México D.F., Mexico

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Abstract

In this paper we report experiments of arterial pressure (AP) measurements of ten Wistar rats subjected to geomagnetic field changes and to artificially stimulated magnetic field variations. Environmental electromagnetic effects were screened using a semianechoic chamber, which allowed us to discern the effects associated with geomagnetic storms. We stimulated the subjects with a linear magnetic profile constructed from the average changes of sudden storm commencement (SSC) and principal phases of geomagnetic storms measured between 1996 and 2008 with $\mathrm{Dst} \leqslant -100\ \mathrm{nT}$. Although we found no statistically significant AP variations, statistically significant AP changes were found when a geomagnetic storm occurred during the experimental period. Using the observed geomagnetic storm variations to construct a geomagnetic profile to stimulate the rats, we found that the geomagnetic field variations associated to the SSC day were capable of increasing the subjects AP between 7% and 9% from the reference value. Under this magnetic variation, the subjects presented a notably restless behavior not seen under other conditions. We conclude that even very small changes in the geomagnetic field associated with a geomagnetic storm can produce a measurable and reproducible physiological response.

Keywords: Geomagnetic storms; Simulated geomagnetic storms; Arterial pressure in rats

1. Introduction

Geomagnetic storms (GS) affect space-borne or ground-based technological systems and may even affect living organisms, and in particular, the human cardiovascular systems (Vencloviene et al., 2013).

The Dst index is frequently used as an indication of the GS relative strength (Gonzalez et al., 1994; Hamilton et al., 1988; Spencer et al., 2013; Kalegaev et al., 2015). The GS's are categorized as weak ($\mathrm{Dst} < -30\ \mathrm{nT}$), moderate ($\mathrm{Dst} < -50\ \mathrm{nT}$), strong ($\mathrm{Dst} < -100\ \mathrm{nT}$), severe ($\mathrm{Dst} < -200\ \mathrm{nT}$) and great ($\mathrm{Dst} < -350\ \mathrm{nT}$) (Olawepo and Adeniyi, 2014).

It has been observed that the Dst associated to a GS typically shows a three-phase pattern: a sudden storm commencement (SSC), followed by a period of fast decay or principal phase (PF) and finally a recovery phase (RF) where gradually the Dst returns to its quiet time value. Although this is the canonical behavior, the SSC can be present or not (Takahashi et al., 1991; Feldstein et al., 2000; Spencer et al., 2011) (see Fig. 1).

Life on Earth has evolved in the presence of natural magnetic fields everywhere, and several studies indicate that biological systems respond to a wide range of magnetic field intensities (e.g. Zhang et al., 2014; Khabarova and Dimitrova, 2009; Krylov et al., 2014; Yu and Shang, 2014). There are an important number of papers concern-

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[*] Corresponding author. Fax: +52 55 56 22 41 13x13.

E-mail addresses: lenica@geofisica.unam.mx, lenica_nube@yahoo.com.mx (J.L. Martínez-Bretón), blanca@geofisica.unam.mx (B. Mendoza).

[1] Fax: +52 55 56 22 41 13x13.

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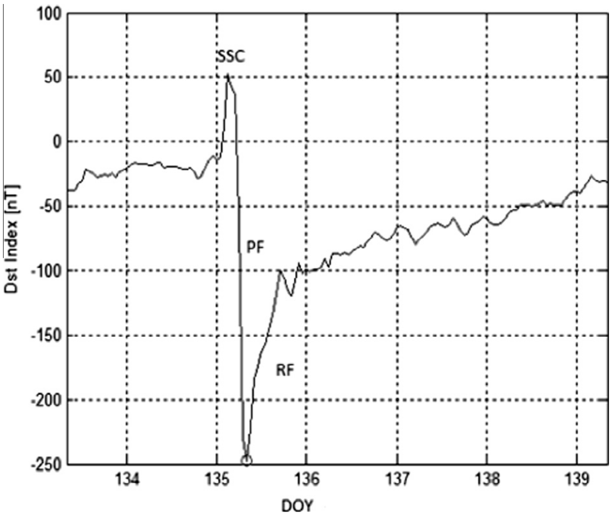

Fig. 1. The three phases of a geomagnetic storm through the Dst index: the sudden storm commencement (SSC), the principal (PF) and recovery (RF) phases. The DOY corresponds to day of the Year.

ing geomagnetic activity and human health. Recent studies dealing with such problem are for instance: Shaposhnikov et al. (2014), who correlated meteorological and geomagnetic factors with myocardial infarctions and brain strokes; Vencloviene et al. (2013), who correlated solar activity and meteorological variables with myocardial infarctions and cardiac health; Mavromichalaki et al. (2012), who found a correlation between geomagnetic activity and cardiac health; Gurfinkel et al. (2012), correlated temperature and geomagnetic activity with vascular parameters; Papailiou et al. (2011), using data from aviators, showed a significant correlation between heart rate variations and high levels of geomagnetic activity and strong cosmic ray intensity decreases; Stoupel et al. (2011), after a twenty year study reported variations in physiological parameters associated with cosmic rays, solar and geomagnetic activity, in particular the finding that cardiovascular health was affected; Mendoza and Sánchez de la Pena (2010), reviewed many papers finding correlations between geomagnetic activity and human health at middle and low geomagnetic latitudes; Khabarova and Dimitrova (2009), found an influence of environmental parameters such as atmospheric pressure, temperature or geomagnetic activity on cardiovascular health; and Dimitrova et al. (2009), found a good correlation between increases in systolic and diastolic pressure and a significant increase in geomagnetic activity.

Furthermore, there are also studies reporting specifically arterial pressure changes during the day before a GS, a time including a SSC: Dimitrova et al. (2004) found that participants presented pressure increases under weak local geomagnetic changes and when major and severe global geomagnetic storms took place. Dimitrova et al. (2009) reported an increase in systolic and diastolic pressure.

In the present paper, we paid special attention in separating the effects of the geomagnetic field variations from the ambient magnetic field variations on physiological processes. Moreover, we identified which phase of the GS caused the largest physiological responses.

2. Geomagnetic storm indices

2.1. Data

For the derivation of the Dst index, four magnetic observatories, Hermanus, Kakioka, Honolulu, and San Juan are used. These observatories were chosen on the basis of the quality of observations, that their locations are sufficiently distant from the auroral and equatorial electrojets and that they are distributed in longitude as evenly as possible (http://wdc.kugi.kyoto-u.ac.jp/dstdir/dst2/onDstindex.html). The Dst index is the hourly average of the data. There is also the SYM-H index that has a one-minute resolution and is constructed similarly to the Dst. It calculates the symmetric portion of the magnetic field horizontal component (H) near the equator (Wanliss and Showalter, 2006).

To assess the GS behavior we used the Dst and SYM-H indices and the H data. The indices are found in the Space Physics Data Facility OMNIWeb (http://omniweb.gsfc.nasa.gov/form/dx1.html) and the WDC_Kyoto (http://wdc.kugi.kyoto-u.ac.jp/index.html). The H data was obtained from the Teoloyucan Magnetic Observatory (TEO) (http://geomaglinux.geofisica.unam.mx/) INTERMAGNET network (http://www.intermagnet.org/data-donnee/download-eng.php), respectively. The TEO observatory has the following geographic coordinates: latitude 19.75° N, longitude −99.17° W.

2.2. Methodology

We used two time periods: the first one from January 1996 to December 2008 and the second one from the 4th of February to the 10th of April 2014. Fig. 2a shows the Dst behavior of the WDC_Kyoto data during the latter period.

The first period data was used to construct a mean GS profile. We searched for strong GS ($\text{Dst} < -100$ nT) in the three databases from 1996 to the end of 2008, finding 15 GS registered in the three observatories. They appear in Table 1. We obtained the SSC and PF phase's means of the 15 GS, and constructed two profiles named eSSC and ePF, respectively shown in Fig. 3a and b. During the second period of the experiment, there was only one GS with $\text{Dst} < -100$ nT. It did not present a SSC as such, but a gradual increase of the Dst during approximately two hours (see Fig. 2b) the 18th of February 2014. The PF minimum the 19th of February 2014 at 9:00 UT with $\text{Dst} = -112$ nT, and the RF persisted up to the 27th of February, 2014. We used the 18th of February data (the gradual increase data), subtracting the H average for that day ($H = 27611.9$ nT) to obtain the variations with respect to this average, to construct a profile named Profile_GS shown in Fig. 3c.