Sq variation analysis from a repeat stations array mounted perpendicular to the dip equator

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Abstract We study the north-south symmetry of the geomagnetic field at low latitudes using quiet and disturbed solar days to analyze their variation patterns. We considered daily variation data for H and D magnetic components from a geomagnetic observatory (Kourou) and two magnetic repeat stations (Centenario and Juába) array near and perpendicular to the magnetic meridian (dip = 0 **°**) at north of the South America and located in different magnetic hemispheres. Also, we analyze a possible interference in H and D daily variation using as reference data from Vassouras Geomagnetic Observatory located to in the north border of the SAMA center.

Introduction

The ionosphere is the ionized part of Earth's upper atmosphere (60 km to 1000 km altitude), this upper layer is ionized by solar radiation. The daily variation is produced by dynamo action in the ionosphere, where thermal and gravitational tides move plasma through the magnetic field and it generates this complex Sq (Solar Quiet) current system (Gubbins, D., & Herrero-Bervera, 2007). The Sq current system has local and time dependence modifying its values, also, with respect to the seasons, latitude and longitude (Koch, S., & Kuvshinov, A., 2015).

The Sq current system is composed of two large current vortices on the either side of the magnetic equator. The daily variation of the geomagnetic field component is due to the Sq current and equatorial electro jet (EEJ). The EEJ is the eastward current flows within the E region of the ionosphere due to the increase in Sq current.

Daily variation of geomagnetic field at low latitudes is associated with stable solar wind flow. The variability occurs at all hours of the day. Its magnitudes in the D, H and Z components have the same diurnal variation, which peaks at noon period like Sq(H) in low latitudes, and a weak seasonal variation which peaks at the June solstice (local summer). The results of previous studies suggest that ionospheric conductivity mainly controls the magnitude, while the electric field and solar winds control the phase and randomness of the day-to-day variability of the hourly amplitudes of Sq (Okeke F.N., et al., 1998).

The Kp-index is the global geomagnetic storm index and is based on three hour measurements of the K-indices, for a given value (Du, D. et al., 2010). The Kp-index measures the deviation of the most disturbed horizontal component of the magnetic field on fixed stations worldwide with their own local K-index. The result is the global Kp-index. The Kp-index ranges from 0 to 9 to a quasi-logarithmic scale, where 0 value means that there is very little geomagnetic activity and a value of 9 means extreme geomagnetic storming (Wanliss, J. A. et al., 2014).

The South Atlantic Magnetic Anomaly (SAMA) is one of the most important anomalies of the geomagnetic field. It is caused by the non-concentricity of the Earth and its magnetic dipole. Continually changing in the space and time, the SAMA encompasses most of the South Atlantic Ocean and parts of South America, South Africa and Antarctica (Badhwar G., 1997). The SAMA center is taken as the minimum intensity locus in the South Atlantic, with a minimum value around 22,500 nT and now it is located close to Asunción city, Paraguay. The SAMA's effect can be observed by some Latin American geomagnetic observatories. The Vassouras Magnetic Observatory (VSS) in Brazil and Pilar (PIL), Las Acacias (LAS) and La Quiaca (LQA) in Argentina supply measurements where is possible to observe that the SAMA's influence is apparent (Hartmann, G. A., & Pacca, I. G. 2009).

The SAMA's variation shows a possible cause of significant longitudinal variations of the Sq in the geomagnetic field intensity and declination angle (Abdu M. A. et al., 2005). The longitudinal variations has been studied by ground and satellite observations. (Koch , S. Kuvshinov A., 2015).

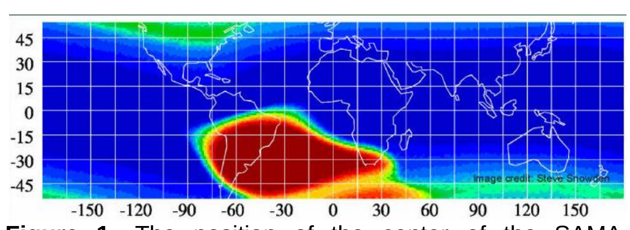

Figure 1: The position of the center of the SAMA (*www.nasa.gov*)

The goal of this work is to study the symmetry of the daily variation using the H and D magnetic components in three geomagnetic stations (KOU, JUA and CEN) situated at low latitudes for quiet and disturbed days. A station is located over the dip equator (I = 0º), and the others are situated equidistant and perpendicular to the dip equator in different magnetic hemispheres and practically at the same geomagnetic longitude. Also we want to compare these data with the VSS measurements to analyze a possible SAMA interference in the daily variation. The lists of used magnetic stations with their coordinates are shown in the below table.

Stations	Cod	Geogr. Latit.	Geogr. Long
Kourou	KOU	5.21° N	52.74° W
Juába	JUA	2.38° S	49.55° W
Centenario	CEN	8.98° S	47.20° W
Vassouras	VSS	22.40° S	43.66° W

***Table 1** The location of magnetic stations*

Figure 2 Map of magnetic observatories stations represented by red houses

Methodology and results

In this analysis we are considering four stations: KOU, JUA, CEN and VSS during a month, October-2011 (figure3). Also, we are using only days extremely quiet and perturbed, as quiet days: 2nd and 3th October and perturbed days: 24th and 25th October. To make the final selection we use the Kp index, which is a global index, and we chose a day which very little geomagnetic activity: 3th October with Kp-index = 2, and the day most disturbed: 25th October with Kp-index= 4 (figure 4).

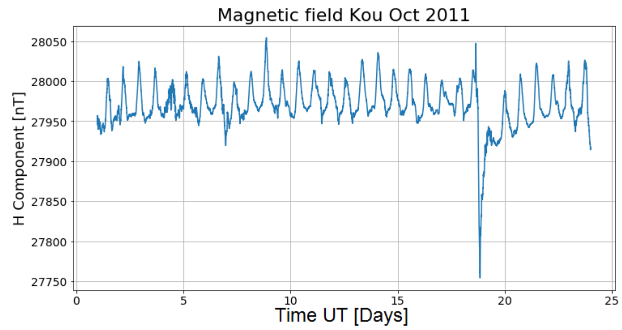

Figure 3 Geomagnetic H-component Kou

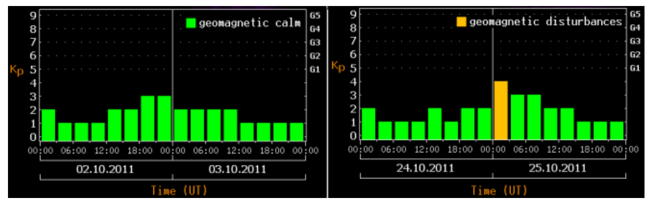

Figure 4 Kp Index (http://tesis.lebedev.ru/en/magnetic_storms)

The 12th Geomagnetic Reference Field (IGRF) was used to correct the the data. This method allows to correct some regional effects and secular variation effects.

Quiet day on 3th October 2011:

The diurnal variations in the two components (H and D) of the four magnetic stations are illustrated in Fig. 5.

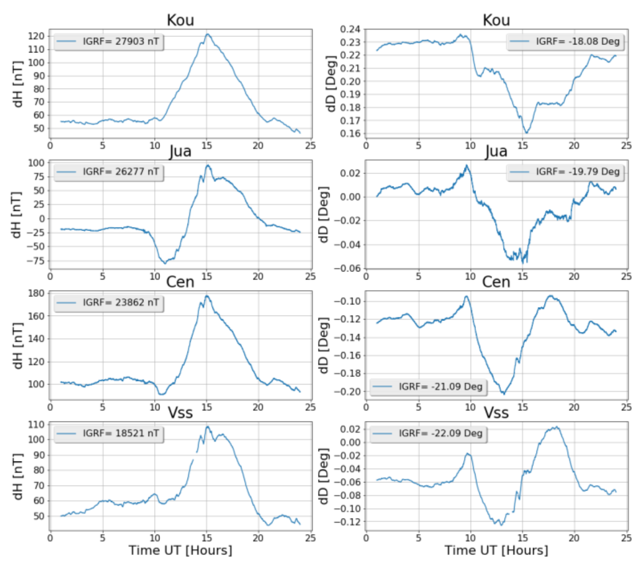

Figure 5: Plot of Sq-dH and Sq-dD from the stations: Kourou, Juába, Centenario and Vassouras on 3th October 2011.

Disturbed day on 25th October 2011:

The variations in the two components (H and D) in presences of a disturbed magnetic of the three repeat stations are illustrated in Fig. 6.

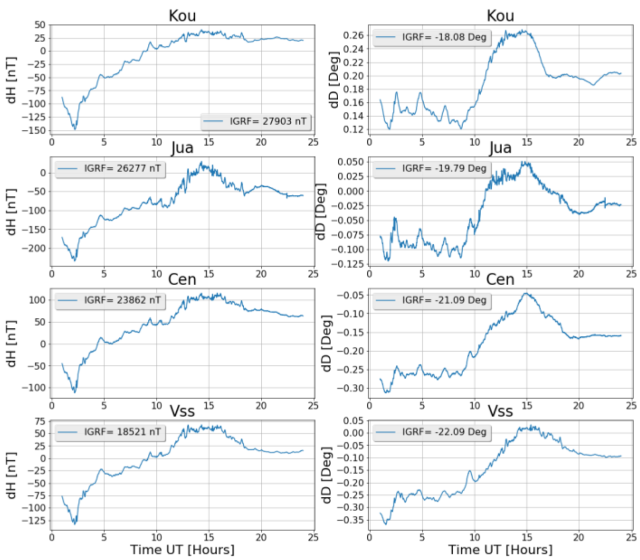

Figure 6: Plot of dH and dD of disturbed day from the stations: Kourou, Juába, Centenario and Vassouras on 25 October 2011.

Discussion

We describe in Fig. 5 (quiet day), H component variation of the geomagnetic field showing the maximum values around midday in local time, also it maintains regular patterns and a consistent variation in all this region. H and D shows regular daily variation during the day and night but they are more conspicuous in the daytime. Our results are in conformity with another's papers using data got at equatorial zones at different parts of world (Rastogi R. et al., 2004; and Rigoti, A. et al., 1999). The latitudinal variation result has a maximum at the dip equator (I = 0º) and a continuous decrease on the northern and southern hemisphere of the magnetic equator until the latitude that defines the edge of the electrojet belt.

It is seen that the D component variations at the CEN station (Fig. 5) exhibit a bit different pattern in amplitude and phase compared with the KOU and JUA stations. This could suggest to be due to the SAMA location, this different pattern is greater compared with KOU and JUA. The amplitude of the H component in VSS is the lower compared with the other stations.

In JUA (Fig. 5), the day to day variability in H and D have amplitudes up to 175 nT and 0.175 Deg, respectively, the greatest amplitudes of the four stations, because the JUA station is located at the EEJ region.

Figure 6 shows that H and D components exhibit a pattern very similar in amplitude and phase between the four stations in presence of the magnetic perturbed. At the JUA station has the greatest amplitudes among the four stations.

Conclusions

The similar patterns of variations for the H component at three stations in the equatorial region (quiet day) reaches its maximum point during the day at local noon, this may suggest a variation due to the stable solar wind flow and the dynamo action from ionosphere that modifies the geomagnetic field.

D component has different features in amplitude and phase on quiet day among the stations (KOU, JUA, CEN, VSS), it could be due to presence of the SAMA or local irregularities in EEJ current system.

H and D components in disturbed day, exhibited similar pattern in amplitude and phase in all four stations, this suggests that the geomagnetic storm can influence on the H and D components in a similar way at low latitude

During the quiet and perturbed days KOU and CEN showed symmetry for H component in amplitude and phase.

So, for this analysis on Sq variation for quiet and disturbed solar days on a magnetic stations array near and perpendicular to the dip equator (dip = 0º), we found symmetry among the KOU and CEN stations for its H component, these stations are located equidistant to the dip equatorial. Furthermore, we observed that D component has different features in amplitude and phase thus we consider that difference can be due to the influence of SAMA.

Acknowledgements

We wish to thanks the CAPES for a fellowship. Also we thanks the REBOM project and the INTERMAGNET for the magnetic data and to the ON's geomagnetism technician Ronaldo Marins de Carvalho.

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