A study of Sq variations recorded at islands from South Atlantic Magnetic Anomaly and a correlation with their geologies

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Abstract

In this study, it was evaluated the diurnal variation of the horizontal (H), declination (D) and vertical (Z) components of the Earth's magnetic field for five stations, four of them located in continental islands in different latitudes and longitudes in relation to the center of the South Atlantic Magnetic Anomaly (SAMA) and another one in the continent. This station in the continent, is close to the center of the anomaly and it was included to be used as a non-island reference. This work shows an analysis made for September 2014, and it considers the geology's dependency to the diurnal variation measured in each station and other factors that can also influence this evaluation.

Introduction

It is known that the South Atlantic Magnetic Anomaly (SAMA) can be considered the biggest anomaly in global bias and it is located, currently, in the south-central region of the South-American continent. It is externally associated to an extensive region above the anomaly that because of the weak magnetic field, the entrance of particles in the magnetosphere is facilitated.

Considering the Brazilian continental dimensions, another phenomenon of importance is situated in the north region of the country, as it can be observed in the Figure 1. The Equatorial Electrojet (EEJ) is situated around 120 quilometers over the DIP Equator (I=0) and behaves anomalous in the region because of the SAMA. It is possible to observe that in regions farther from the SAMA it has practically a linear behavior, but as it passes through South America, under the influence of the SAMA, the Dip equator will be "pulled" for the anomaly center. This fact shows the importance to study this regional effect for SAMA and EEJ comprehension.

The data were collected in four magnetic observatories located at South Atlantic islands, another one is situated in the continent. We intended in this study to correlate the diurnal variations with local geologies and possible SAMA interference.

We considered three components of the Earth's magnetic field: horizontal (H), declination (D) and vertical (Z), taking into account internal and external influences of the main magnetic field. The magnetic stations were chosen according to theirs proximities to the center of the SAMA, as it can be observed in the Figure 1. The chosen stations were: Ascension Island (ASC) and Tristan da Cunha (TDC), this islands being located between the South-America and African continents, being ASC located in the northeast border of the SAMA and practically not sensible to its effects. Port Stanley (PST) and King Edward Point (KEP), islands located in the south of the South America and Pilar (PIL), the only one station located in the continent, is placed in Argentina next to the center of the anomaly and it will be used as a reference for comparison with the island stations. The geographic and geomagnetic coordinates can be seen in the Table 1.

The used data were from September 2014 and we choose three principal magnetic quiet and disturbed days by the kp index. Thus, we correlated these results with the possible influence from SAMA and EEJ.

	Geographic		Geomagnetic	
Observatory	Latitude (º)	Longitude (º)	Latitude (º)	Longitude (º)
Ascension Island (ASC)	7.949 South	345.624 East	2.809 South	057.530 East
King Edward Point (KEP)	54.282 South	323.507 East	46.163 South	029.844 East
Pilar (PIL)	-31.667 North	296.117 East	-20.61 North	05.73 East
Port Stanley (PST)	51.704 South	302.107 East	42.309 South	012.349 East
Tristan da Cunha (TDC)	-37.067 South	347.685 West	-41.35 North	67.20 East

Table 1. Geographic and Geomagnetic coordinates of the stations.

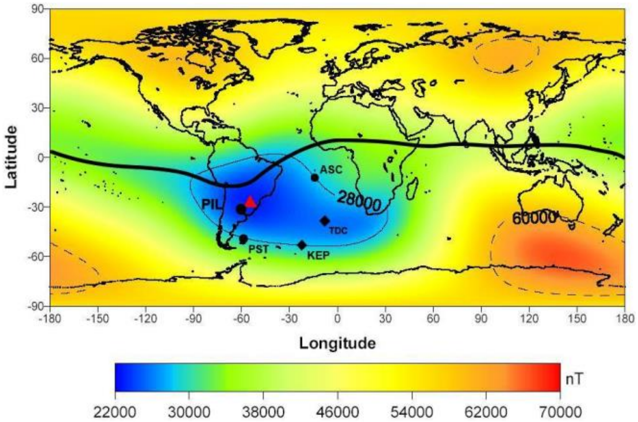

Figure 1. Geographic distribution of the observatories studied and the EEJ (Hartmann and Pacca, 2009).

Method

In this study we used H, D and Z components and we intended to correlate the local geology on the diurnal magnetic variation due the SAMA and EEJ influences.

Using the kp index, from the International Service of Geomagnetic Indices (ISGI), it was verified the international quiet and disturbed geomagnetic days for the period which can be seen in the Table 2.

Quiet Days	14	15	08	17	20
Disturbed Days	12	19	24	26	27

Table 2. Five Quiet and five Disturbed Days for September 2014.

This choice to study geomagnetic quiet and disturbed days, is useful to determine which stations are more influenced by the magnetic field generated in the ionosphere and which can be more influenced by the local geology, such observations can be made by variations in the components used.

In this analyze we are considering the data format as IAGA2002 (minute) and the hourly mean of the data was used to observe the variations over the month.

The baseline chosen was to take the monthly mean for the mean values of the first two and last two hours of each Day, it was done for the entire month when data was available and was done for all components separately. The data were treated for cyclic variations with linear adjustment.

The magnetically quiet and disturbed days were analyzed to verify the influence on the H component, making a correlation with the EEJ. In addition, the presence of SAMA and also the local geology of each station were taken into account to verify the influence on the components D and, mainly, Z. Other longer periods were chosen to be observed according to their amplitudes and variations, to analyze jointly the variations and correlate the three components used.

Geological Considerations

The geomagnetic station of King Edward Point is located on the South Georgia Island. The main rock exposure is formed by two laterally equivalent turbidity sequences and KEP is located on the Cumberland Formation, which is basically composed of andesitic volcanoclastic greywackes derived from a volcanic island arc (Tanner and MacDonald, 1982).

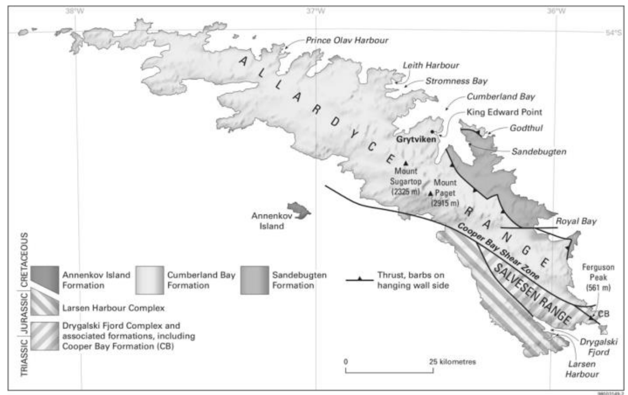

Figure 2. South Georgia Island.

The Falklands islands were formed by the subduction of the South America Plate with Sandwich plate. These islands, in the most parts, are composed with basalt. On average 60% is composed of lava and 40% by material fragment by volcanic eruption.

The station of Port Stanley is located on the Falklands Islands, on the Port Stanley Formation, which is formed mainly by quartz sediments.

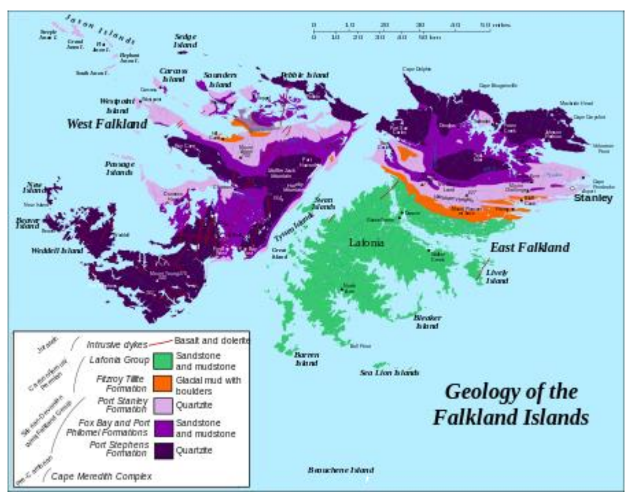

Figure 3. Geology map of the Falkland Islands.

The islands of Ascension and Tristan da Cunha runs along the Mid Atlantic Ridge in the South Atlantic Ocean, they are volcanic islands formed by hotspots.

Ascension is a volcanic island with only a single volcano. It is located on the South America Plate. Mafic and silicic pyroclastic deposits are distributed across the island, much of them are trachyte, rhyolite and obsidian, all igneous rocks. As these types of rocks have a medium magnetic susceptibility so Z values will be influenced.

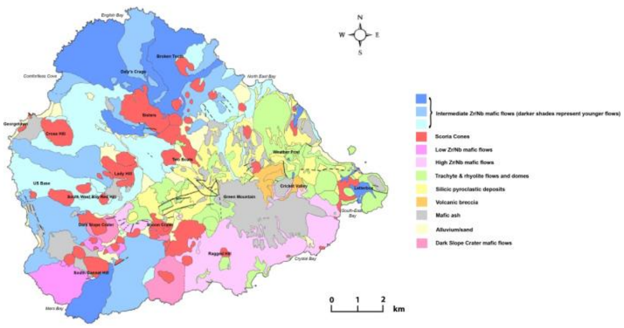

Figure 4.Geology map from the Ascension Island.

The Island of Tristan da Cunha is formed by alternating layers of volcanic ash and lava flows.

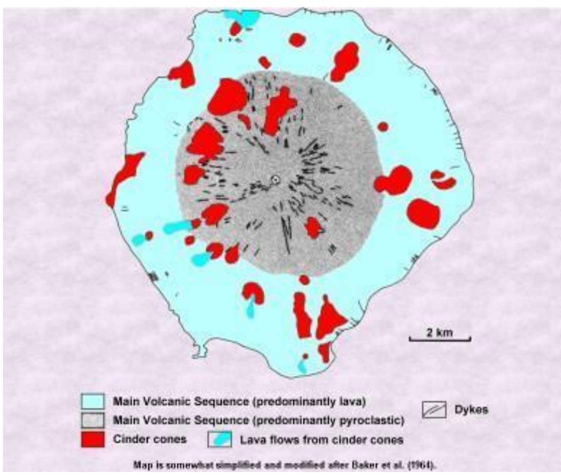

Figure 5. Geology map from Tristan da Cunha.

The geomagnetic station of Pilar is on the center of the South America continent and its geology is mainly marine sediments.

Results

Figures 6, 7 and 8 shows the respective values to H, D and Z components for September 14th, 15th and 20th which are considered magnetically quiet days and 12th, 19th and 24th disturbed days.

It is possible to observe in the figures that due to the lack of data caused by interruptions, there are incomplete sections in the graphs presented.

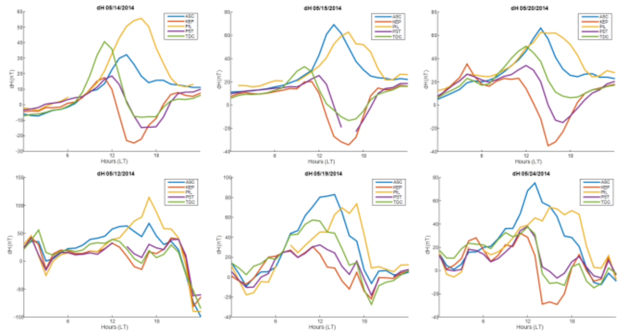

Figure 6. Quiet and Disturbed Days chosen for H.

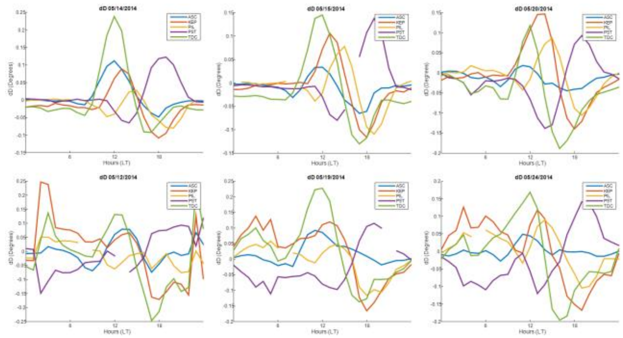

Figure 7. Quiet and Disturbed Days chosen for D.

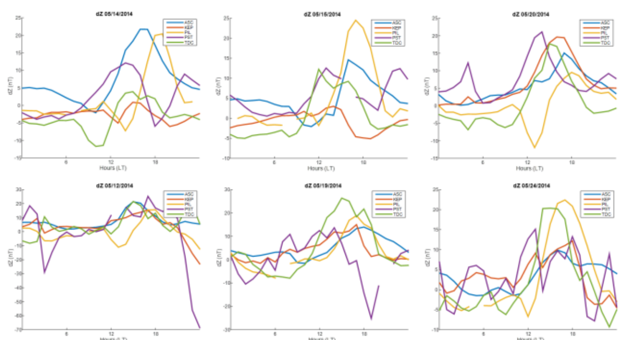

Figure 8. Quiet and Disturbed Days chosen for Z.

In Figure 6, can be observed variations of the H component for each station. It is possible to observe that the curves of ASC on the disturbed days had a greater amplitude variation compared to the other ones, this result was expected since it is the closest station to the EEJ. The other stations are less affected by the EEJ because of their geographic locations. This fact could be observed in the behavior of the curves that showed a lower intensity variation in this component, even if on the quiet and disturbed days.

As can be observed on the Figure 7 for D component it is possible to verify a similar amplitude variation on the quiet days for all analyzed stations and a more erratic behavior for disturbed days. KEP and PST are stations with the biggest fluctuations for the quiet days. The maximum variation occurs between 10 and 12 hours, and the minimum can be observed around 16 hours for the D component for all collected data. The PST's curves showed an opposite behavior, with a minimum variation around 12 hours and maximum around 18 hours. TDC and KEP curves presented a maximum around 11 and 13 hours, respectively.

Component Z curves are shown in Figure 8. It is possible to perceive that the behavior of the curves does not remain the same on the days presented. However, ASC curves maintained a more definite pattern even on the disturbed days, having a maximum variation around 16 hours and a minimum around 10 hours. TDC and PIL curves presented interesting opposite variation for the most part of the days, assuming around 14 and 16 hours concavities in the same direction, besides presenting a small phase difference.

Discussion and Conclusions

Analyzing the geology of TDC and ASC stations it can be seen a considerably high magnetic susceptibility. Being these stations more sensitive for sq variations and because they are farther from the center of the SAMA, it is expected that their curves present a greater amplitude of variation in H component.

The ASC station has the smallest variation in the graphics observing the H, D and Z components, and it has the higher intensity for H component, because its proximity to the EEJ and big distance to the center of SAMA.

Since PIL is a continental station, it presents a more consistent Z curve for all days, which is related to the local geology since its local sediments have low magnetic susceptibility. This is not observed for the H component considering its proximity to the SAMA center.

Considering the latitude and longitude of TDC, it is the one with the lowest field intensity, by the association of its position within the SAMA zone of influence, the distance to the EEJ and the local geology.

The phase difference associated with the maximum in D component for PST can be related to the contribution of the Z component, and this difference was also noted by Kuvshinov et al (2007). Due to the variations observed in PST for the Z component, it seems to be more sensitive to variations related to geology, although it is formed mainly by sediments of low magnetic susceptibility which shows that there may be influence of other factors like it was observed by Maus and Kuvshinov (2004). It is also possible to observe an apparent similarity between the variations for the H component in the disturbed days which can be associated to being farther to the SAMA.

Despite the fact that local geology has influence on the interpretation of the data for the Z component, Maus and Kuvshinov (2004) attribute the induction of electric currents in the ocean as a more significant influence for island stations.

The KEP station data show low variations for the H and Z components despite the morphology of the curves. For the D component, the stations of KEP and PST shows curves with opposite variations and morphology and considering the H component, both of which vary similarly, a behavior expected because they are far from the EEJ and closer to the SAMA. The D variation being more influenced by Z, shows a correlation with to the morphology considering the fact that KEP has higher magnetic susceptibility while PST has a greater presence of quartz sediments on its formation.

In this analysis, focusing in the disturbed and quiet days, we concluded the interference of the SAMA for the main field analysis and how it can decrease the Sq variations considering the stations position. The influence of the geology along the others mentioned local factors can be observed to be of great relevance for the Sq variations in islands with high magnetic susceptibility sediments.

Acknowledgements

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