Local Geomagnetic Model for the First Magnetic Observatory of Honduras

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Abstract

As a preliminary step to install the First Magnetic Observatory of Honduras, the local geomagnetic components are being computed in Tegucigalpa, Honduras, for the temporal interval 2010 − 2013, using the Tsyganenko and Sitnov 2005 (*J. Geophys. Res.* **110**, A03208, 2005: TS05) semi-empirical magnetospheric model. The diurnal variation of H (Sq) is obtained from the Chiripa Observatory (Costa Rica) data, using the International Quiet Days and the Normal Orthogonal Component Analysis. Pearson's correlation coefficients are being calculated between the H-component computed with the TS05 model in the Tegucigalpa coordinates and the Chiripa Observatory (CRP) data. The better correlations are obtained in days with Kp < 4, when the Sq and the quiet daily variation are removed from the CRP-H data and the TEG-H_{TSY}-component respectively. Seven TS05 magnetospheric currents are obtained in order to evaluate their contribution in the Sq. Using the Normal Orthogonal Component Analysis, the Chapman-Ferraro current fits better in the 0.00 − 12.00 local time interval, and the Birkeland currents fits better in the 12.00 − 24.00 local time interval.

1. Introduction

Space Weather (SWE) is about the electromagnetic perturbations and energetic particle events driven by changes in the Sun's magnetic field and solar wind (SW) and by their effects on Earth's magnetic field and upper atmosphere, that affects the Earth's space, atmosphere and surface environments (Thomson, 2012; Schrijver, 2015). SWE affects our modern way of life, some times in very dramatic ways, and its potential to impact is growing.

Geomagnetic storms consist of disturbances of the magnetic field of our planet, having a minimum duration of several hours and a maximum duration of several days. The amplitudes with which storms are observed in different locations are greater the higher the latitudes and mainly affect electrical systems, satellites, high-altitude aircraft and radio communications.

Magnetic observatories provide local measurements of space weather conditions and free data centres provide near-real-time magnetic data from many observatories (i.e., INTERMAGNET, World Data Centres for Geomagnetism of Kyoto and Edinburgh), valuable for analysis of global and regional space weather activity. Different products offered by them are helpful to use with models that simulate or predict impact on the environment and technologies (Thomson, 2012). We consider that since there is no magnetic observatory in Honduras and therefore data for ionospheric, magnetospheric and terrestrial core currents in Tegucigalpa, the TS05 model is suitable because it includes fundamental processes in the magnetosphere (terrestrial and satellite data) such as charge exchange, energy inputs and outputs of geomagnetic storms and thus compared with reference data from the closest magnetic observatory of the region, Chiripa.

The computing of TEG-H_{TSY}-component is the basis for the design and creation of a magnetic observatory in Honduras, to introduce and carry out future work in the fields of space weather and geophysical research and implementation.

2. Computing the TEG-H_{TSY}-component

The x-, y- and z-components of the International Geomagnetic Reference Field (IGRF) were computed using the Geopack-2008 code from Nicolai Tsyganenko. The same Cartesian components were computed for the magnetosphere, using the Tsyganenko and Sitnov's TS04 code. From these components we obtained the sum of IGRF's H-component plus magnetosphere's H-component, formally named TEG-H_{TSY}. Figure 1 shows these series versus Chiripa Observatory data (CRP-H) for the time interval 2010 − 2013.

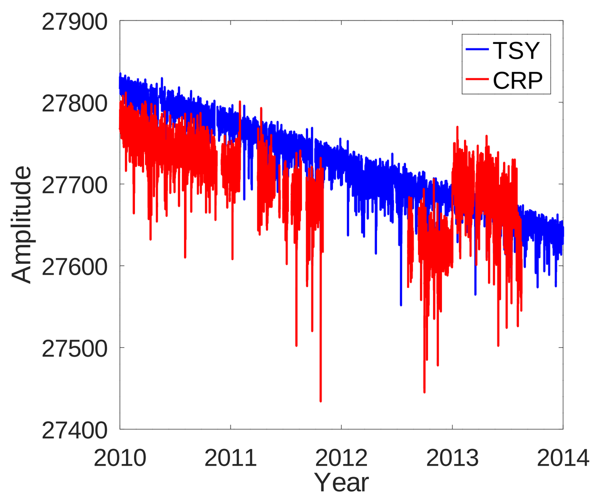


Figure 1: TEG-H_{TSY} values (blue) versus CRP-H data (red) obtained from World Data Centre for Geomagnetism, Edinburgh.

3. Sq Variation

The Sq variations that are measured on the Earth's surface contain both ionospheric currents and secondary currents induced inside the Earth. Several studies have shown that these Sq variations could be contaminated by the effect of various magnetospheric currents (see Yamazaki and Maute, 2017).

The Sq-H was computed in two ways: a) using the International Quietest Days (IQD) data of the CRP observatory for the 2010 − 2013 interval; b) applying the Singular Value Decomposition Analysis to the CRP-IQD data and selecting a model with 2 modes (Castillo et al., 2017):

$$\mathbf{Q} = \mathbf{USV^T}, \text{ where :}$$

$\mathbf{Q}$ is the data matrix of quietest days, with size 147 x 24 (the rest of quietest days were removed because contain gaps); $\mathbf{U}$ is a matrix 147 x 147, with the normalized eigenvectors of the matrix $\mathbf{QxQ^T}$; $\mathbf{V}$ is a matrix 24 x 24, with the normalized eigenvectors of the matrix $\mathbf{Q^TxQ}$; $\mathbf{S}$ is a matrix 147 x 24 matrix, with 24 singular values of $\mathbf{Q}$.

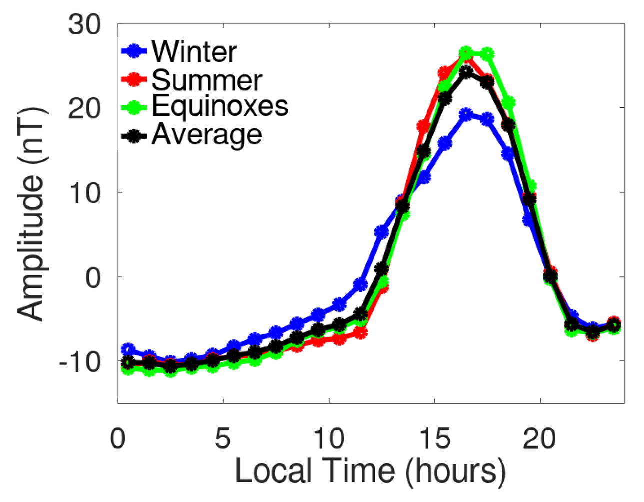


Figure 2:Lloyd's seasons plots represent the mean of the quietest days data of Chiripa in Winter, Summer, and equinoxes. Black plot is the annual average.

4. Magnetospheric Currents

The quietest-days values of the magnetospheric currents are obtained using the International Quietest Days. These values are projected into the Chiripa's Sq-model (CRP-NOC-Sq-H), in order to measure their contribution to the Sq daily variation.

In the noon-midnight local time interval, the Chapman-Ferraro projections are the largest ones (Figure 3). In the midnight-noon interval, the Birkeland currents are the largest (Figure 4).

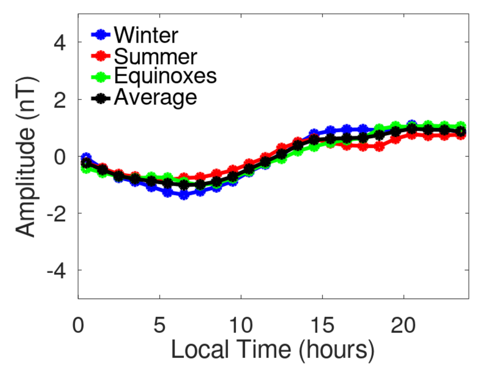


Figure 3: Chapman-Ferraro Lloyd's plot.

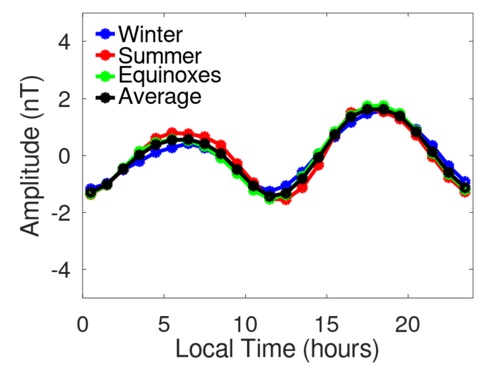


Figure 4: Birkeland Lloyd's plot.

5. Pearson's Cross-correlations

CRP-H time series were compared with the corresponding TEG-H_{TSY} using the Pearson correlation coefficients r with p-values ≤ 0.05.

$$r(A, B) = \frac{cov(A, B)}{\sigma_A \sigma_B}$$

Where cov(A,B) is the covariance between CRP-H and TEG-H_{TSY}, σ_A and σ_B are the corresponding standard deviations.

As can be seen in Figure 5, better correlations are obtained when both the Sq in CRP-H and the QDV in TEG-H_{TSY} are removed (right panel). For more details, see Castillo et al., 2017.

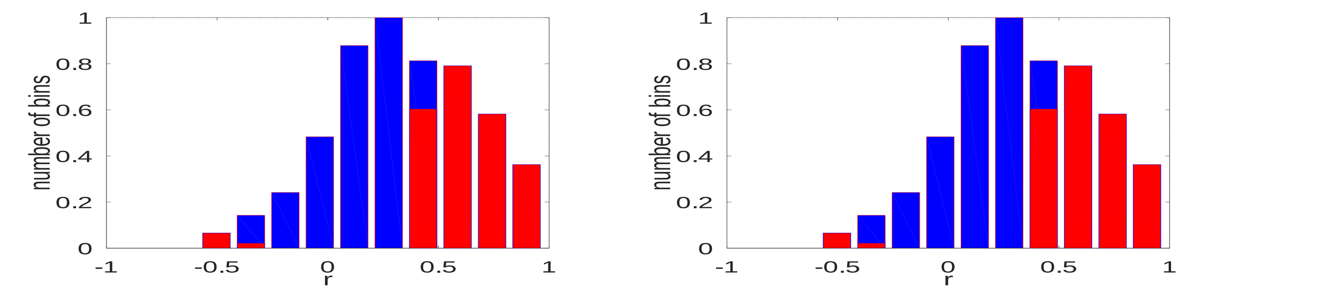


Figure 5: Left: r between CRP-H and TEG-H_{TSY}. Right: r between CRP-H-wo-Sq and TEG-H_{TSY}-wo-QD. In both, blue bars are the counts with p-value > 0.05. Red bars are the counts for p-value ≤ 0.05.

6. t-Welch test

The Levenberg-Marquardt algorithm was used to fit correlations to Gaussians (z-Fisher transformation). In the Welch t-test, the correlations of raw data are compared with the corrected correlations. Figure 6 shows the resulting values of the Welch t-test comparing CRP-H vs. TEG-H_{TSY} with CRP-H-wo-Sq (removing Sq signal) vs. TEG-H_{TSY}-wo-QD (removing quietest days signal) in days with Kp < 4 (z-Fisher mean $= 0.56$). For active days, when the diurnal variation is subtracted, there is not a significant change when we compare the same correlations(see Figure 7), because these are large values and just a small value of diurnal variation is subtracted (z-Fisher mean $= 0.55$).

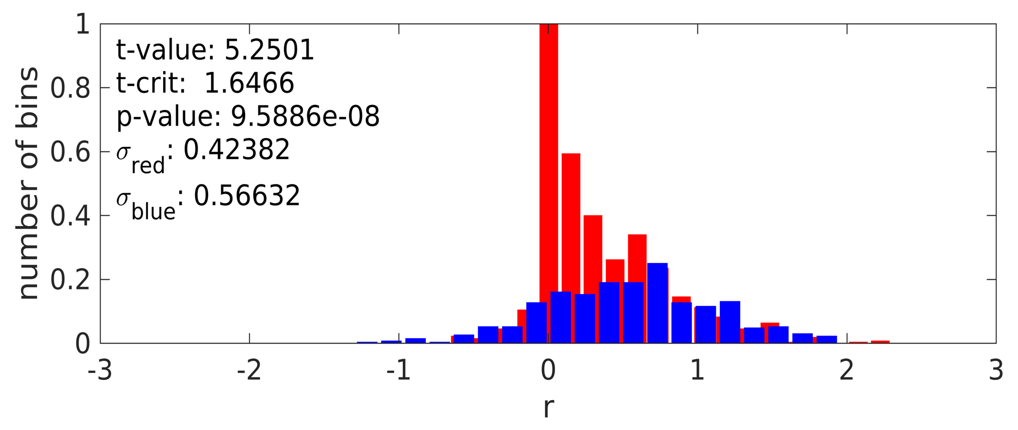
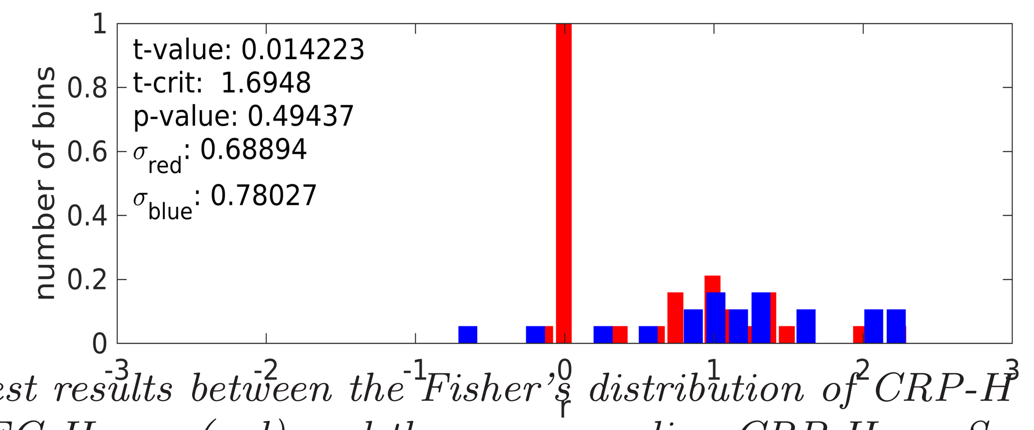


Figure 6 : t-test results between the Fisher's distribution of CRP-H versus TEG-H_{TSY} (red) and the corresponding CRP-H-wo-Sq versus TEG-H_{TSY}-wo-QD (blue), in days with Kp < 4.



t-test results between the Fisher's distribution of CRP-H versus TEG-H_{TSY} (red) and the corresponding CRP-H-wo-Sq versus TEG-H_{TSY}-wo-QD (blue), in days with Kp ≥ 4.

7. Conclusions

- In days with Kp < 4 the correlations improve when the Sq and the QDV are removed from data and the model respectively. We consider that this is because TEG-H_{TSY} do not include the ionospheric neither the crustal field.
- In days with Kp ≥ 4, the correlations do not improve when we remove the Sq neither the QDV. We conclude that this is because both the Sq and the QDV are small compared with the storm-time values.
- The projection of magnetospheric currents into the Sq model shows that Birkeland projection is the largest one in the noon-midnight local time interval and the Chapman-Ferraro projection is the largest in the midnight-noon interval, due the magnetosphere's dawn-dusk asymmetry (see Tsyganenko and Sitnov 2005 and references therein).

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