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Statistical and spectral study of geomagnetic storm forecasting

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The purpose of this study is to analyze the associated spectrum of geomagnetic field, frequencies intensity and the time of occurrence of geomagnetic storms. Also, we set out to analyze the possibility of predicting these geomagnetic storms.

A geomagnetic storm is a temporary disturbance of the Earth's magnetosphere caused by solar coronal mass ejections, coronal holes or solar flares. Solar wind shock wave typically strikes the Earth’s magnetic field 24 to 36 hours after the event.

This only happens if the shock wave travels in a direction toward Earth. The solar wind pressure on the magnetosphere will increase or decrease depending on the Sun's activity. These solar wind pressure changes modify the electric currents in the ionosphere. The data used in this paper are acquired within the Surlari Observatory, and additional information to characterize the geomagnetic storms analyzed, we obtained from the specialized sites such as www.intermagnet.org and www.noaa.gov. Information about geomagnetic data from other observatories, as well as planetary physical parameters allowed us to perform comparative studies between the data recorded in different observatories.

We calculated the variation of the correlation coefficients, with mobile windows of various sizes, for the recorded magnetic components at different latitudes and latitudes. Also, we have used for this purpose a series of filtering algorithms, spectral analysis and wavelet with different mather functions at different levels.

Wavelets allow local analysis of magnetic field components through variable frequency windows. Windows that contain longer time intervals allow us to extract low-frequency information, average ranges of different sizes lead to extraction of medium frequency information, and very narrow windows highlight the high frequencies or details of the analyzed signals. The wavelet functions describe the orthogonal bases with signal approximation properties, while the orthonormal bases in the Fourier analysis are made up of sinusoidal waves.

Estimation of geomagnetic field disturbances is similar to the standard problem of estimating a signal disturbed by signal theory.

The term noise refers to any modification that changes the periodic or quasi-periodic characteristics of the original signal.

The Dst index is used to assess the severity of geomagnetic storms and to determine the effects of the solar wind on space and terrestrial infrastructures and is very important to be able to predict the effects of the geomagnetic storm.

The numerical experiments presented in this paper are part of different methodological categories, with the same purpose, but with different approaches. The common goal is the prediction of geomagnetic disturbances and the methodologies used comparatively are Fourier spectral deconvolution, autoregressive models on time series and recurrent Long Short Term Memory (LSTM) neural networks that are capable of long-term dependence.