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# Wavelet-based fractal analysis of InterMagnet Observatories data

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## Abstract

The main goal of the paper is to used the so-called Hurst exponent estimated by linear regression of the modulus of the continuous wavelet transform of the horizontal component of a given InterMagnetc observatory data versus the scales for geomagnetic storms prediction and analysis. Application to Wingst observatory data of the Mai 2002 period shows clearly that the Hurst exponent can be used as an index for geomagnetic storms analysis, prediction and detection. Keywords: Hurst exponent, wavelet transform, storms, index, prediction, detection.

## 1. Introduction

The purpose of this paper is to use the fractal analysis to detect and establish a schedule of geomagnetic disturbances by analyzing data from the International Real-time Magnetic Observatory Network (INTERMAGNET) observatories. This will be achieved by the use of fractal formalism revisited by the continuous wavelet transform. Several techniques have been applied for prediction of geomagnetic disturbances (Ouadfeul and Hamoudi, 2012). In this paper, we analyze signals by the fractal formalism to predict geomagnetic storms and provide a schedule of geomagnetic disturbances. The technique of maximum of modulus of the continuous wavelet transform is used. We start the chapter by giving some definitions in geomagnetism. We then give a short description of magnetic storm and its effects. The proposed methods of analysis are then applied to data recorded by different observatories.

## 2. The magnetic storms

Solar activity modulates the transient variations of the geomagnetic field. In particular, the undecennal cycle is clearly seen in the temporal distribution of sunspots as well as the magnetic activity as highlighted by the variation of the K or Dst indices. The increase in electron density due to the solar wind in different layers of the ionosphere would vary the intensity of the geomagnetic field causing many effects. Monitoring the solar activity can help to predict certain disturbances in the propagation of waves whose effects can be serious for telecommunications, as well as the impact of these storms on the distribution of electrical energy. In 1965, a massive power failure plunged the North American continent in the dark, or 30 million people out of 200 000 km2 (Ouadfeul and Hamoudi, 2012). In 1989, a failure of the same origin affected 6 million people in Quebec (Canada). The auroras produced by this storm were visible over Texas.

## 3. Dst index

The geomagnetic Dst index is an index that tracks the global magnetic storms. It is built by the average of the horizontal component H of the geomagnetic field measured at mid-latitude observatories. Negative values of Dst indicate a magnetic storm in progress. The minimum value of Dst indicates the maximum intensity of the magnetic storm.

## 4. Fractal analysis of observatories data

To analyze data from InterMagnet observatories, an algorithm was developed (Figure 01). It is based on the estimation of local Hurst exponents at maxima of modulus of the Continuous Wavelet Transform (CWT).

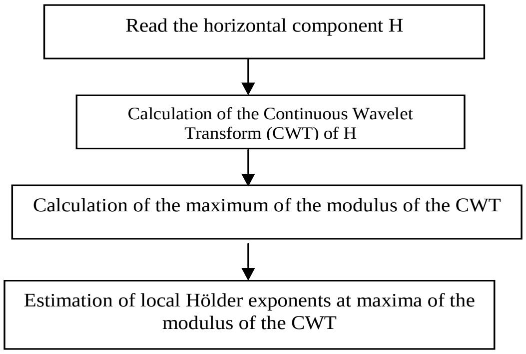


Figure 01 Flowchart for estimating local Hurst exponents on WTMM

## 5. Wingst observatory data analysis for May 2002

We analyze the Wingst magnetic observatory (Germany) data recorded during May 2002. This period saw large geomagnetic disturbances. We analyzed the horizontal component of the magnetic field. This last is calculated from the X and Y components. Figure 2 shows this component versus the time. The modulus of the continuous wavelet transform is calculated using the complex Morlet analysing wavelet.

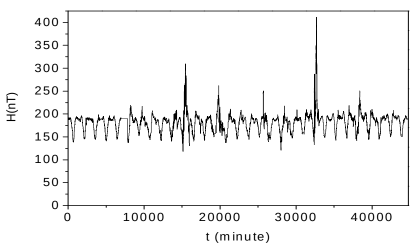


Figure 02 Horizontal component of the magnetic field recorded by the Wingst observatory during the month of May 2002.

The next step consists to calculate the Hurst exponents at the local maxima of the modulus of the continuous wavelet transform. Note that the calculation of Hurst exponents at maxima of the modulus of the CWT is the core of this analysis. Indeed, this is the point which can differentiate the proposed method over other methods based on the Hurst exponent estimation. This method allows us to save time by calculating the Hurst exponents only at representative times of magnetic disturbances. To compare the obtained results with the Dst index, we calculated an average value of the Hurst exponents for each hour of the month. The obtained results are shown in Figure 3.

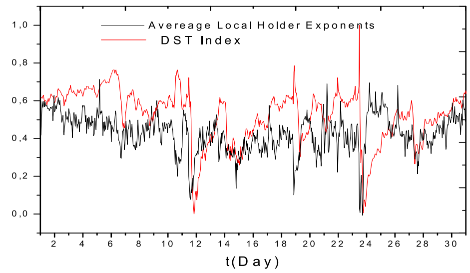


Figure 03 Average Hurst exponents compared with the Dst index .

## 6. Results, interpretation and conclusion

It is clear that the horizontal component H is characterized by a Hurst exponent of very low value at the moment of the magnetic storm (Figure 3). Each event is characterized by a peak in the curve of the Dst index. A detailed presentation between days 8 to 13, showing the behaviour of the Hurst exponent before, during and after the magnetic storm. We observe that hours before the storm are characterized by progressive decrease of the Hurst exponent to reach the minimum value h = 0.07 at t = 11.55day (11th day and 13.20 hours). After the storm, we observe a gradual increase of the Hurst exponent.
During a magnetic storm, the Hurst exponent of the horizontal component H has a very low value. Before the storm we observe gradual drop of the Hölder exponent. Several numerical experiments realized using vertical component Z recorded by magnetic observatories show that, as expected, this component is not sensitive to the magnetic disturbances.

## References

[1] Ouadfeul, S., Hamoudi, M, 2012, Fractal analysis of InterMagnet Observatories data, ed (Ouadfeul), Fractal analysis and Chaos In Geosciences, Intech, ISBN 978-953-51-0729-3.