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Multifractal analysis of the InterMagnet Observatories data using the Generalized Fractal Dimensions.

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Abstract

In this paper, we use the so-called the Wavelet Transform Modulus Maxima lines (WTMM) technique for estimation of the capacity, the information and the correlation fractal dimensions of the Intermagnet Observatories time series. Analysis of Hermanus, Baker-Lake, Kakioka, Albibag and Wingst observatories data shows that the correlation and the information dimensions can be used a supplementary indexes for geomagnetic disturbances identification.

Keywords: WTMM, fractal Intermagnet, capacity, information, correlation, dimension, disturbances.

1. Introduction

The fractal behaviour of the geomagnetic field recorded by magnetic observatories placed at the earth surface has been used for geomagnetic disturbance analysis and identification. Ouadfeul and Hamoudi (2012a) have used the estimated local local Holder exponents at maxima of the modulus of the continuous wavelet transform, obtained results show that the Holder exponent decrease before the geomagnetic disturbances, at the moment of the perturation the local Holder exponent has a very low value. In this paper, we will demonstrate the usefulness of generalized fractal dimension D(q) to establish a calendar of magnetic disturbances. We will apply this technique at the data of many InterMagnet observatories data. Two important periods are analyzed. One is the month of May 2002 and the second is the period of October and November 2003.

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, 2012a). 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. The generalized fractal dimensions as an index of magnetic disturbances

The first step is to apply the WTMM technique to data of each hour of the month, that is to say, every 60 samples. The objective is to estimate the spectrum of exponents τ (q). Then we compute the generalized fractal dimensions for the following values of q: 0, 1 and 2. The following formula is used (Ouadfeul et al, 2012b):

$$D(q) = \frac{\tau(q)}{(q-1)}$$

Note that for D (1) we use the limit of D (q) when q tends towards 1.

Figure 01 presents of the flow chart of the proposed technique.

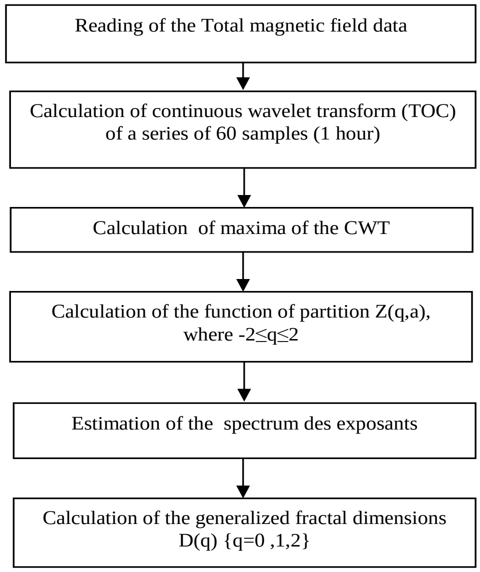

Figure 01 Flowchart of the total magnetic field analysis using the generalized fractal dimensions.

4. Hermanus observatory data analysis for May 2002

The first record to be processed is the total field recorded by the Hermanus observatory during the period of May 2002. The total field variations are shown in Figure 02. Obtained results show the non sensitivity of the fractal dimension D_0 to the magnetic disturbances. However, for the generalized fractal dimensions D_1 and D_2, the main magnetic disturbances are characterized by peaks.

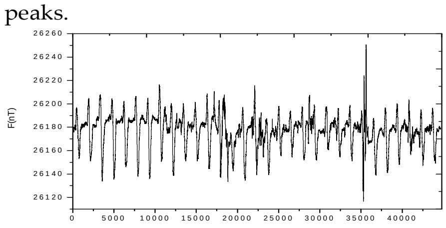

Figure 02 Magnetic field recorded during May 2002 by the Hermanus observatory

5. Results, interpretation and conclusion

Data of many geomagnetic observatories of the InterMagnet network are analyzed by the generalized fractal dimension over the period of Many 2002 and October-November 2003. These periods have known big geomagnetic disturbances. Obtained results show that the fractal capacity dimension is not always sensitive to geomagnetic disturbances rather than the correlations and the formation fractal dimensions. These dimensions are good candidates as geomagnetic indexes that can represent the geomagnetic disturbances.

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