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RESEARCH ARTICLE

FRACTAL DIMENSIONAL ANALYSIS OF GEOMAGNETIC aa INDEX

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ABSTRACT

Climate change is the most studied concept in the world of research. Various new techniques like Neural Networks, learning Non- linear dynamics and others are used to predict climate change. Solar activity may be a major forcing of climate change. In this paper we use aa index as an indicator of solar variability and study its trend using Hurst's exponent method. The Fractal dimensional value of aa index was calculated to be 1.1 for a period of 1900 -2010. This value of aa index shows a "persistence" that is the future trend is more and more likely to follow an established trend.

INTRODUCTION

Both the rainfall and temperature are the tools to study the effect of climate change. These two parameters are in general inversely related to sunspot numbers, although the results of some of these studies are conflicting (1).we have utilized hundred years of continuous data of proxy data representative of solar variability(geomagnetic indices aa) for a period 1901-2010. For this analysis, we preferred the use of aa index instead of sunspot numbers. Although a good indicator of solar variability sunspot do not directly affect interplanetary environment. However aa index treated as a measure of turbulent plasma in the ecliptic planes. Represented disturbances (in the ecliptic plane) at the position of earth. The aa index has been retrospectively calculated from 1868(2). It is defined by the average, for each 3-hour period, of the K indices from two near-antipodal stations after the transformation of K into amplitudes (nT). Despite its simplicity, the index is a useful measure of global geomagnetic activity and provides one of the longest high-resolution data sets which can be used in the analysis of solar-terrestrial phenomena. Since the aa index is related to the weather parameters, it becomes essential to understand the behaviour of aa index. In order to find the predictable nature of aa index we use the Hurst exponent method. This method provides a measure of predictability of the parameters considered. This value can be used as guide to select appropriate parameters (data) for weather forecasting.

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The Hurst exponent, *H*, is defined in terms of the asymptotic behaviour of the rescaled range as a function of the time span of a time series as follows

$$E\frac{R(n)}{S(n)} = Cn^H \text{ as } n \rightarrow \infty,$$

Where [R(n)/S(n)] is the rescaled range, E(x) is the expected values and n i the time span of the observation (number of data point in a time series). C is a constant.

Calculating the Hurst exponent

To calculate the Hurst exponent, one must estimate the dependence of the rescaled range on the time span *n* of observation(3). A time series of full length *N* is divided into a number of shorter time series of length n = N, N/2, N/4, ... The average rescaled range is then calculated for each value of *n*. For a (partial) time series of length *n*, $X= X_1,X_2...X_n$, the rescaled range is calculated as follows:

1. Calculate the mean : m
2. Create a mean-adjusted series:$Y_t=X_t- m$ for t= 1,2,...n
3. Calculate the cumulative deviate series Z:
4. Compute the range R;
5. Compute the standard deviation S;
6. Calculate the rescaled range R(n) / S(n) and average over all the partial time series of length n. The Hurst exponent is estimated by fitting the power law to the data.

The Hurst exponent is related to the fractal dimension D of the time series curves by formula (4)

$$D= 2-H$$

If the fractal dimensions D for the time series is 1.5 there is no correlation between amplitude changes corresponding to two successive time intervals. Therefore no trend in amplitude can be discovered from the time series and hence the process is unpredictable. however as the fractal dimensions decreases to 1, the process becomes more and more predictable as it exhibits "persistence", that is the future trend is more and more likely to follow an established trend (5). As the fractal dimension decreases from 1.5 to 2, the process exhibits ' anitipersistence". That is a decrease in the amplitude of the process is more likely to lead to an increase in the future. Hence the predictability again increases. However, we will be concerned only with persistence behaviour since all geophysical time record analysed till date (6) exhibit behavior.

Data and Analysis

The aa index data is obtained for a period of 1900-2010 downloaded from www.ukssdc.ac.uk/cgi-bin/wdcc1/secure/ geophysical_data_options.pl. The Hurst exponent value for the aa index for hundred years was calculated using the above mentioned steps. The fractal dimension value obtained was D=1.1 for the aa index. In a time series forecasting we would like to know that the series under study is predictable or not. If the time series is random the entire model designed based on it is expected to fail. The Hurst exponent value of aa index for hundred and Ten years shows a more predictable trend. Thus the aa index can be used as a tool to study the climate change and effect of solar forcing on earth's climate

Conclusion

In this paper we have analyzed the Hurst exponent value for the geomagnetic aa index for a period of hundred and Ten years and was found to be 1.1. This suggests that the aa index has a predictable nature which can be learnt by other techniques like neural network to benefit forecasting.

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