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International Journal of Current Research
Vol. 3, Issue, 11, pp.055-056, November, 2011

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

FRACTAL DIMENSIONAL ANALYSIS OF SUNSPOT NUMBERS

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ARTICLE INFO

Article History:
Received 8th August, 2011
Received in revised form
9th September, 2011
Accepted 8th October, 2011
Published online 20th November, 2011

Key words:
Sunspot numbers,
Hurst exponent,
Fractal analysis.

ABSTRACT

This paper covers an analysis of sunspot numbers and fractal dimension analysis for 104 years. Hurst exponent has been calculated for 104 years to arrive at Fractal Dimensional analysis of sunspot numbers. The results show a less persistent behavior.

INTRODUCTION

A sunspot is a relatively cool area on the solar surface that appears as a dark blemish. The number of sunspots is continuously changing over a period in a random fashion and constitutes a typical, a priori random time series. The solar activity is maximum when more sunspots are present on the surface of the sun. Sunspot number time series is a multivariable, strong coupling and nonlinear time series. Earlier, yearly mean sunspot numbers during 1700-1993 were analyzed by wavelet transform to know the behavior of sunspot numbers and its time series. Although many methods have been proposed to deal with this task, none of them are found suitable for Sun spot number time series. Hurst exponent attaches a useful number to these systems. The Hurst exponent is a parameter that quantifies the persistent or anti persistent behavior of Sunspot number time series. It determines whether a given time series is completely random one or has some long term memory. Fractal dimensional analysis of geophysical time series is a well established investigative tool for exploring the dynamics. Fractal dimensional analysis is particularly well suited to analyse the variability of a given time series.

METHODOLOGY

To calculate the Hurst exponent one must estimate the dependence of re-scaled range on time span n of observation. The time series of full length N is divided in to a number of short time series of length n= N,N/2.N/4…..The average rescaled range is then calculated for each value of n.

For a time series of length n, $X=X_1, X_2, \ldots X_n$, the rescaled range is calculated as follows
*Calculate the mean
*Create a mean-adjusted series
*Calculate the cumulative deviate series
*Compute the Range R
*Compute the Standard Deviation S
*Calculate the rescaled range $R(n)/S(n)$
*Average over all the partial time series of length n
*Using $R(n)/S(n)$,we compute Hurst exponent by using formula $R(n)/S(n) = Cn^H$

Where H is the Hurst exponent. This power law manifests itself as a straight line in the log-log plot of R/S vs W. The H exponent indicates persistent $H>0.5$ or anti persistent $H<0.5$. The Hurst exponent vary between 0 and 1, with higher values indicating a smoother tred, less volatility and less roughness
The Hurst exponent related to Fractal dimension D of the time series curve by the formula

$D = 2 - H$ $\qquad$ $D=2-0.779 =1.221$

When Fractal dimension D for the time series is 1.5, there is no correlation in amplitude change between two successive time intervals and is unpredictable. When Fractal dimension decreases to 1 the process becomes more and more predictable, when fractal dimension increases from 1.5 to 2, the process exhibit anti persistent. Our analysis has given Fractal Dimension D as 1.221.

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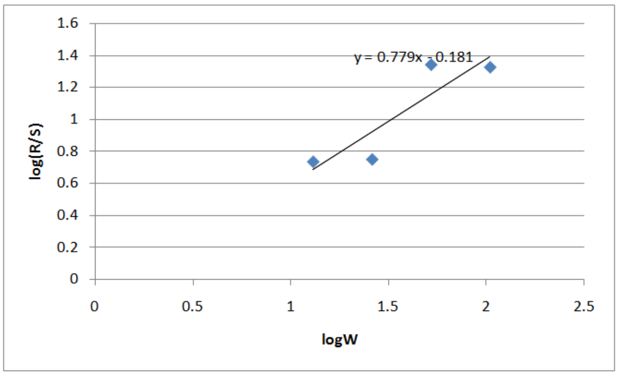
RESULTS AND DISCUSSION

We have considered 104 years (1907-2010) data of sunspot numbers. The Data have been taken from Sunspot Index Data Centre (SIDC). Using the Data, employed R/S method to compute Hurst exponent H. The calculated value of H is =0.779.

	logW	logR/S
104 years	2.017	1.32446
52 years	1.716	1.03929
26years	1.41497	0.752643
13years	1.11394	0.7384413



Graphical analysis has been done by drawing a graph between log w and log R/S. where w is number of years. R/S is rescaled range of number of sunspot numbers observed for 104 years/52years/26years/13years.

CONCLUSION

In this paper we followed the Hurst analysis of sunspot numbers for 104 years and calculated Hurst exponents in each time series. Hurst Exponents calculated for 104 years and Fractal dimension analysis carried out show that the Sunspot number in a time series is predictable.

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