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Fractal Dimension Analysis of Northeast Monsoon of Tamil Nadu

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Abstract:

Analysis of the general rainfall trend is vital for the purpose of forecasting and in identifying the changes and impacts that are very crucial for an agro-based economy like the one of Tamil Nadu. Northeast monsoon data of Tamil Nadu is used for fractal dimension analysis using Hurst exponent method. The Hurst exponent (H) is a statistical measure used to classify time series. It is found that the behavior of Northeast monsoon rainfall in Tamil Nadu is anti-persistent, since the value of fractal dimension (D) is 1.7895

Keywords: Anti-persistent, Fractal dimension, Hurst exponent, Northeast monsoon

1.0 Introduction:

Tamil Nadu is the only sub-division of the Indian union which receives more rainfall in the Northeast monsoon (October- December) season than in the Southwest monsoon. The rainfall received in Tamil Nadu during the Northeast monsoon season is of great economic value. Major agricultural operations are normally undertaken during that season. It has, however, been noted that the rainfall during northeast monsoon is highly variable. Therefore, if its behavior could be predicted in advance, it would go a long way toward helping the agricultural and industrial activities of the region (Dhar and Rakhecha, 1983). In the present study an attempt has been made to investigate Northeast monsoon rainfall of Tamil Nadu using fractal dimension analysis.

Fractal analysis provides a unique insight into a wide range of natural phenomena. Fractal objects are – those which exhibit 'self-similarity'. This means that the general shape of the object is repeated at arbitrarily smaller and smaller scales. Coastlines have this property: a particular coastline viewed on a world map has the same character as a small piece of it seen on a local map. New details appear at each smaller scale, so that the coastline always appears rough. Although true fractals repeat the detail to a vanishingly small scale, examples in nature are self - similar up to some non-zero limit. The fractal dimension measures how much complexity is being repeated at each scale. A shape with a higher fractal dimension is more complicated or 'rough'than one with a lower dimension, and fills more space. These dimensions are fractional. The fractal dimension successfully tells much information about the geometry of an object. Very realistic computer images of mountains, clouds and plants can be produced by simple recursions with the appropriate fractal dimension.

Fractal dimensional analysis is calculated using Hurst exponent method. The Hurst exponent, proposed by H. E. Hurst for use in fractal analysis (Mandelbrot and Van Ness, 1968), has been applied to many research fields. Since it is robust with few assumptions about underlying system, it has broad applicability for time series analysis (Mandelbrot, 1982). The values of the Hurst exponent range between 0 and 1. The fractal dimension value thus obtained is used as an indicator to examine the predictability of Northeast monsoon rainfall of Tamil Nadu. The objective of this study is to analyse the behavior of Northeast monsoon rainfall of Tamil Nadu using fractal dimension.

2.0 Data used

We have used the Northeast monsoon rainfall data of Tamil Nadu from the period 1902- 2008. The data are obtained from the Regional Meteorological centre, Chennai.

3.0 Fractal Dimensional Analysis

3.1 Hurst exponent method

There are several methods for estimating the fractal dimension of a time series of data such as the box counting method and the correlation method (DeGrauwe, Dewachter and EmbrechtS, 1993) (peitgen and Saupe, 1988). The applications of these methods are often demanding in computing time and require expert interaction for interpreting the calculated fractal dimension. We have used Hurst exponent method in this paper. It provides a measure for long term memory and fractality of a time series. For calculating Hurst exponent, one must estimate the dependence of the rescaled range on the time span *n* of observation. Various techniques has been adopted for calculating Hurst exponent. The eldest and best-known method to estimate the Hurst exponent is R/S analysis. The rescaled analysis or R/S analysis is used due to its simplicity in implementation. It was proposed by Mandelbrot and Wallis (Mandelbrot and Wallis, 1969), based on the previous work of Hurst (Hurst, 1951).

The R/S analysis is used merely because it has been the conventional technique used for geophysical time records (Govindan Rangarajan and Sant, 1997). 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*, the rescaled range is calculated as follows: (Samuel Selvaraj, Umarani, Vimal Priya and Mahalakshmi, 2011)
Calculate the mean;
Create a mean-adjusted series;
Calculate the cumulative deviate series *Z*;
Compute the range *R*;
Compute the standard deviation *S*;

Calculate the rescaled range *R* (*n*) / *S* (*n*) and average over all the partial time series of length *n*.
Hurst found that (R/S) scales by power-law as time increases, which indicates

$$(R/S)n = c*n^H$$

Here c is a constant and H is called the Hurst exponent. To estimate the Hurst exponent, we plot (R/S) versus n in log-log axes. The slope of the regression line approximates the Hurst exponent.
The values of the Hurst exponent range between 0 and 1. Based on the Hurst exponent value *H*, the following classifications of time series can be realized:
$H = 0.5$ indicates a random series;
$0 < H < 0.5$ indicates an anti - persistent series, which means an up value is more likely followed by a down value, and vice versa;
$0.5 < H < 1$ indicates a persistent series, which means the direction of the next value is more likely the same as current value (Alina Barbulescu, Cristina Serban and Carmen Maftei*, 2007)*

The Hurst exponent is related to the Fractal dimension D of the time series curve by the formula

D = 2 - H (Voss, In: pynn, Skjeltorp, 1985)

The parameter H is called the Hurst exponent which takes the value between 0 and 1. If the fractal dimension D for the time series is 1.5, we again get the usual random motion. In this case, there is no correlation between amplitude changes corresponding to two successive time intervals. Therefore, no trend in amplitude can be discerned from the time series and hence the process is unpredictable. However, as the fractal dimension decreases to 1, the process becomes more and more predictable as it exhibits persistence behavior. That is the future trend is more and more likely to follow an established trend. As the fractal dimension increases from 1.5 to 2, the process exhibits anti-persistence. That is, a decrease in the amplitude of the process is more likely to lead to an increase in the future (Govindan Rangarajan and Sant, 2004).

4.0 Results and Discussion

As shown in fig. 1 a graph is plotted for log n vs log R/S and the slope is calculated for the given time series. The slope for the dataset is found to be 0.2105, which is the Hurst exponent. So, the Northeast monsoon rainfall of Tamil Nadu follows anti-persistence pattern. The fractal dimension D takes the value of 1.7895 using the Hurst exponent. The fractal dimension D also exhibits anti-persistent behavior.

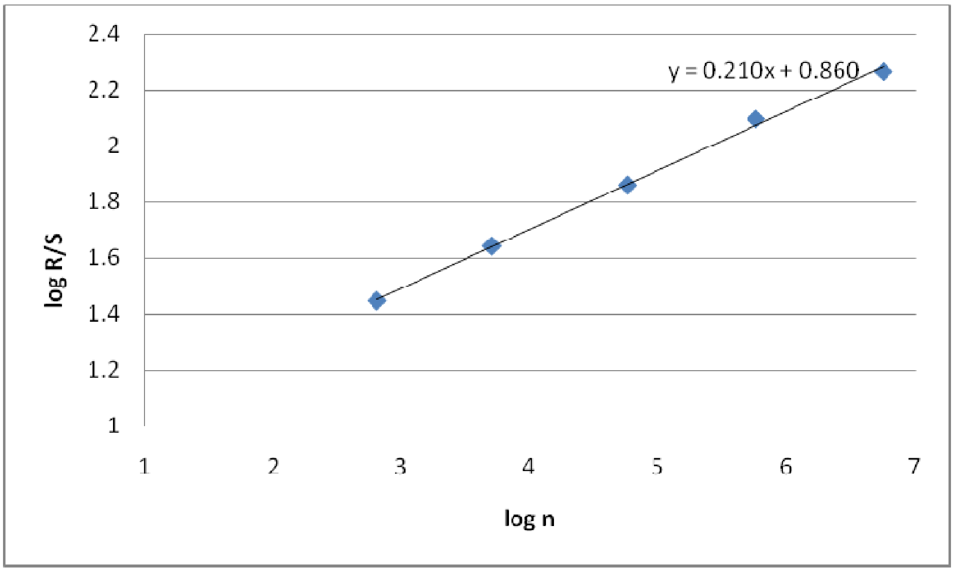

Fig 1: Plot for the Calculation of Slope in the Hurst Exponent

5.0 Conclusion

Since the Hurst exponent provides a measure for predictability, we can use this value to guide data selection before forecasting. We can identify time series with large Hurst exponents before we try to build a model for prediction. Furthermore, we can focus on the periods with large Hurst exponents. This can save time and effort and lead to better forecasting.

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