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Scaling Analysis of the Flare Index Data from Kandilli Observatory

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Abstract. The daily time series Flare Index (FI) data of Northern Hemisphere, Southern Hemisphere and Total Disk for Solar Cycle 21- 23 and 24 up to Dec. 2014 has been pre-processed using a 2nd order exponential smoothing algorithm to remove orthogonal noise. The smoothed data in each case is processed for scaling analysis using Rescaled-Range Analysis as well as Finite Variance Scaling Method in order to search for the Hurst exponent. As the value of H obtained from our analysis lies in between 0 and 1, so it can be said that the signal may behave like Fractional Brownian Motion. Also, it is observed that H is less than 0.5 which indicates the data is anti-persistent in nature and it has a strong negative correlation within the signal. The value of H also indicates the oscillating features of the signal which might have some fundamental periodicities in the Suns atmosphere.

Keywords. Flare Index Data, Exponential Smoothing, Rescaled-Range Analysis, Finite Variance Scaling Method, Hurst Exponent, Short Range Dependent memory

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1. Introduction

The dynamics of astronomical as well as astrophysical phenomena is very important aspect to understand the space weather (Wiegelmann *et al.* 2014). The fractal and chaos theories have a great influence on the way astronomical phenomena is addressed (Zou *et al.* 2014). The astronomical phenomena may be the outcome of a simple process with deterministic chaotic features (Sivakumar 2004). Thus, identification of those complex process requires appropriate algorithm based on the fractal and chaos theories (Marwan *et al.* 2007). The Hurst Exponent is one of the method to bring out statistical characteristics and behaviours (like fractional gaussian noise or fractional Brownian motion) of various astronomical signal according to fractal and chaos theories.

2. Data and Procedure

The short-lived action of the active region of the Sun is measured by a parameter called flare index which permits the analysis of short and long-term variation inside the Suns atmosphere. Therefore, the daily Flare Index data for Northern Hemisphere, Southern Hemisphere and Total Disk during 1976 to 2014[Solar Cycle 21- 23 and 24 up to 31st December, 2014] is collected from Kandilli Observatory for our analysis.

The daily FI data is processed by 2nd order exponential smoothing algorithm (Winters 1960) to filtered out the orthogonal noises within it followed by scaling analysis using Rescaled-Range Analysis (Mandelbrot & Wallis 1969) as well as Finite Variance Scaling Method (Scafetta & Grigolini 2002) in order to search for the Hurst exponent.

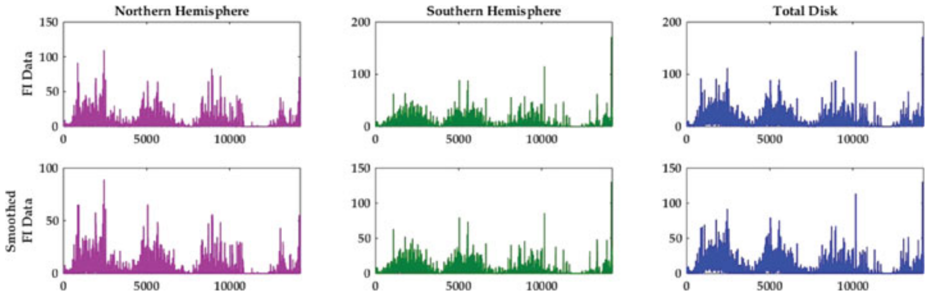

Figure 1. Effect of Smoothing algorithm on Flare Index Data.

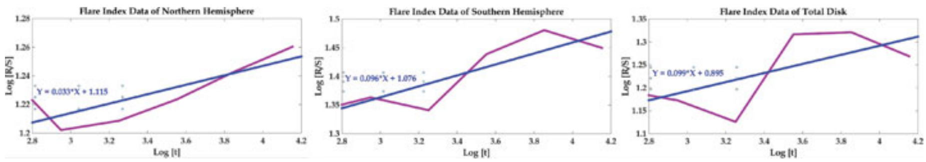

Figure 2. Scaling Analysis of Flare Index Data using Rescaled-Range Analysis.

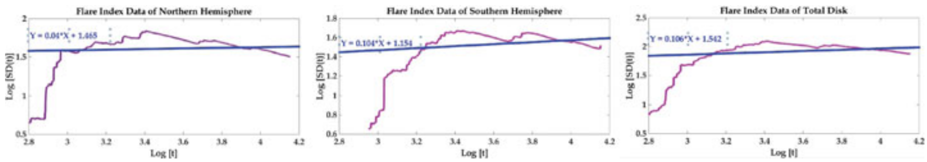

Figure 3. Scaling Analysis of Flare Index Data using Finite Variance Scaling Method.

3. Result and Discussion

The value of H lies in between 0 and 1, so the signal may behave like Fractional Brownian Motion. Also, H is less than 0.5 which indicates the data is anti-persistent in nature with Short Range Dependent memory. Also it indicates oscillating features of the signal which might have some fundamental periodicities in the Suns atmosphere. This oscillating feature also indicates alternating rise and fall of the signal which trends to stabilized the Suns atmosphere i.e. the basic dynamics of the Suns atmosphere is ruled by some negative feedback mechanism. According to anti-persistent theory, any deflection in a negative feedback system are normally corrected by fast over-correction which generates undulation around set point. This produces nonlinear response in the Suns atmosphere.

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