Multifractal Detrended Fluctuation Analysis of Wind Speed Connectivity Density Time Series

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Abstract

Meteorological services have been developing sensors to record environmental parameters with higher and higher frequency; that is crucial to analyse complex, multivariate, and non-linear meteo-climatic phenomena. However, to extract information and understand the underlying dynamical mechanisms of these phenomena, we need robust and advanced statistical methods.

Among the environmental variables, wind speed is very important for the implications in terms of sustainable energy issues. Several studies have been carried out on wind speed, by using machine learning algorithms, time series forecasting, fractal analysis, multifractal analysis, visibility graph, and complex network.

In the present work, we use correlation network and multifractal analysis to investigate the inner structure of the wind speed. Even more, we study the wind phenomena by combining three different aspects: spatial (due to the spatial distribution of the meteorological sensors), temporal (due to the analysis of the network topology on a daily basis), and correlative (due to the selection of the correlation threshold, by which the topology of network is defined).

The study is focused on the daily correlation network (between wind measuring stations) at several thresholds (see Fig. 1). These networks are characterised by the connectivity density, which measure the proportion of wind sensors that are correlated among them. A daily time series of connectivity density is obtained for the period time between 2012 and 2016.

Finally, we apply the multifractal detrended fluctuation analysis (MFDFA) to detect the presence of long-range properties in the connectivity density time series and quantify possible intermittency. As an example, Fig. 2 shows the results of the MFDFA applied on the connectivity density time series for threshold 0.5.

The present study would contribute to better understand the wind processes in complex areas, like Switzerland. Furthermore, it would help a better planning and design of the characteristics of a wind monitoring system.
$\rho_T = 0.7$ and $\Delta = 0.088$

$\rho_T = 0.7$ and $\Delta = 0.012$

**Figure 1:** Correlation networks for two different days considering a threshold of 0.7 (April 9, 2012 and September 4, 2016).

**Figure 2:** MFDFA results for $\rho_T = 0.5$; (a) fluctuation functions; (b) generalized Hurst exponents; (c) $\tau$-function; (d) multifractal spectrum.

**References**
