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Multifractal analysis of forest fires in complex regions

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Forest fires can be studied as point processes where the ignition points represent the set of locations of the observed events in a defined study region. Their spatial and temporal patterns can be characterized by their fractal properties; which quantify the global aspect of the geometry of the support data. However, a monofractal dimension can not completely describe the pattern structure and related scaling properties. Enhancements in fractal theory had developed the multifractal concept which describes the measures from which interlinked fractal sets can be retrieved and characterized by their fractal dimension and singularity strength [1, 2].
The spatial variability of forest fires is conditioned by an intermixture of human, topographic, meteorological and vegetation factors. This heterogeneity makes fire patterns complex scale-invariant processes difficult to be depicted by a single scale. Therefore, this study proposes an exploratory data analysis through a multifractal formalism to characterize and quantify the multiscaling behaviour of the spatial distribution pattern of this phenomenon in a complex region like the Swiss Alps.
The studied dataset is represented by 2,401 georeferenced forest fire ignition points in canton Ticino, Switzerland, in a 40-years period from 1969 to 2008. Three multifractal analyses are performed: one assesses the multiscaling behaviour of fire occurrence probability of the support data (raw data) and four random patterns simulated within three different support domains; second analysis studies the multifractal behavior of patterns from anthropogenic and natural ignited fires (arson-, accident- and lightning-caused fires); and third analysis aims at detecting scale-dependency of the size of burned area.
To calculate the generalized dimensions, Dq, a generalization of the box counting methods is carried out based on the generalization of Rényi information of the qth order moment of the probability distribution. For $q > 0$, Dq indicates the scaling of overdense regions and strong singularities, and for $q < 0$, Dq exhibits the behaviour of small fluctuations (underdense regions) [2].
Multifractal analysis for forest fires in canton Ticino are performed using raw data, the anthropogenic- and natural-caused patterns and the random patterns simulated within the three different support domains. Results of these different patterns are compared. These analyses revealed non-linear behaviour of the generalized dimensions Dq, depicting inhomogeneous nature of the physical fire-ignition conditions as well as the presence of nonlinear interactions between scales.

Keywords: forest fires, point process, box counting, fractal dimension, multifractal.

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