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Multifractal detrended fluctuation analysis of magnitude series of seismicity of Kachchh region, Western India

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ABSTRACT

The sequence of magnitudes of the earthquakes occurred in Kachchh area (Gujarat, Western India) from 2003 to 2012, has been analysed by using the multifractal detrended fluctuation analysis. The complete and the aftershock-depleted catalogues with minimum magnitude M3 were investigated. Both seismic catalogues show multifractal characteristics. The aftershock-depleted catalogue is more multifractal and also more persistent than the whole catalogue; this indicates that aftershock magnitudes contribute to increase the homogeneity and the randomness of the magnitude sequence of the whole seismicity. The singularity spectrum of the whole catalogue, however, is more left-skewed than that of the aftershock-depleted one, indicating a stronger dependence of the multifractality on the large magnitude fluctuations.

1. Introduction

It is well recognized that the earthquakes in Kachchh region are caused by several active faults in various weak geological formations and crustal structures. The faults are stressed in intraplate rift environment and recent inversion tectonics [1]. This is responsible for the heterogeneity of crustal structure and the strain field as well. The crustal deformation comprising of faulting, folding, micro fracturing, joints are accordingly quite complex and their behaviours obey fractal statistics [2]. Therefore, the seismicity generated in this region has fractal characteristics. Most of the existing studies devoted to the fractal characterization of Kachchh seismicity have been focused mainly on the spatial and temporal distribution of seismicity. Mandal et al. [3] estimated the fractal dimension and the Gutenberg–Richter b-value of Kachchh seismicity using the first three months of aftershocks data of the devastating 2001 earthquake occurred in the investigated area. The correlation dimension of the spatial distribution of earthquakes was estimated 1.71 ± 0.02, which indicates that the events approach dimension 2, while the correlation dimension of the temporal distribution of the events was estimated as 0.78 ± 0.02, indicating the mono-fractal structure in time domain. The negative correlation found between spatial correlation dimension and b-value suggested a stress release along faults of a larger area and indicated the predominance of large events associated with weak clustering, implying a reduced probability of large magnitude earthquakes due to fragmentation of the fault zone. Dimri et al. [4] applied the wavelet based fractal analysis on the similar aftershock dataset, obtaining a fractal dimension of 2.06, which indicates that the earthquakes fill the 2D plane. Kayal et al. [5] appraised the tectonics of Kachchh region using

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0378-4371/

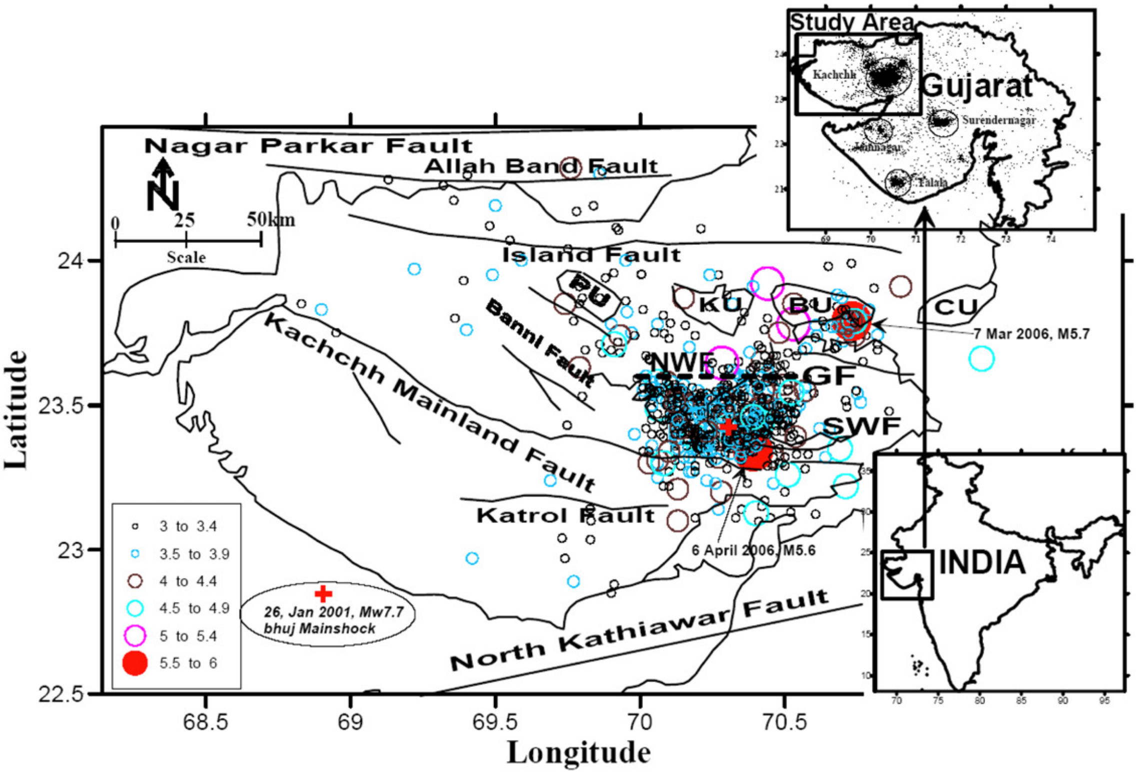

Fig. 1. Map of the seismicity of Kachchh region (Western India).

fractal dimension and the b-value; separating the seismicity in two distinct zones, one along the Kachchh Mainland fault (KMF) and the other along the South Wagad uplift faults (SWF), and found that KMF has higher fractal correlation dimension and b-value than SWF, suggesting that the region could show multifractal characteristics.

Although the analysis of fractal/multifractal characteristics of earthquake sequences has been extensively investigated in the space and time domain [6–12], very few works exist focused on the fractal/multifractal features of the earthquake magnitude sequences. Lennartz et al. [13] studied the long-range correlations of the magnitude sequences in Northern and Southern California by using the detrended fluctuation analysis (DFA) and provided evidence that there is long-term memory in the seismic activity explained in the temporal fluctuations of magnitudes. Varotsos et al. [14] applying the DFA to the magnitude sequence of California seismicity between 1973 and 2003, found that, while in the regimes of stationary seismic activity long-range temporal correlations exist between earthquake magnitudes with a DFA exponent ∼0.6, these correlations break down and the value of the exponent becomes even lower than 0.5, thus showing anti-correlated behaviour, before the occurrence of the largest earthquakes.

In this study, therefore, we focus on the magnitude sequence of the seismicity of the Kachchh that is one of the most seismically active areas of India, and whose multifractal characteristics have not been investigated so far.

2. Data

We analysed the sequence of magnitudes (M_w) of the earthquakes occurred in Kachchh region, Gujarat (Western India) between 2003 and 2012 (Fig. 1) (The catalogue is available at the Institute of Seismological Research, India). We investigated the sequence of earthquakes with minimum magnitude 3.0, which is the completeness magnitude of the investigated area. We analysed both the whole sequence and the aftershock-depleted catalogue. The aftershocks were removed by means of the Gardner and Knopoff's method [15] using the Uhmhammer space–time window [16].

3. The multifractal detrended fluctuation analysis

The multifractal detrended fluctuation analysis (MF-DFA) [17] is a multifractal methodology well known for its simple implementation and effective use. Considering the time series $x(i)$, with $i = 1, 2, \ldots, N$ and N the length of the series, after removing its average x_{ave} we construct the "trajectory" or "profile" by integration

$$y(i) = \sum_{k=1}^{i} [x(k) - x_{ave}] . \quad (1)$$