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Multifractal detrended fluctuation analysis of Pannonian earthquake magnitude series

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HIGHLIGHTS

- The magnitude series of the Pannonian shallow earthquakes are weakly persistent.
- The magnitude series of the Pannonian deep events are almost uncorrelated.
- The multifractal spectrum of deep catalogue is wider than that of the shallow one.
- The deep series has a wider multifractal spectrum and right-skewed.

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ABSTRACT

The multifractality of the series of magnitudes of the earthquakes occurred in Pannonia region from 2002 to 2012 has been investigated. The shallow (depth less than 40 km) and deep (depth larger than 70 km) seismic catalogues were analysed by using the multifractal detrended fluctuation analysis. The shallow and deep catalogues are characterized by different multifractal properties: (i) the magnitudes of the shallow events are weakly persistent, while those of the deep ones are almost uncorrelated; (ii) the deep catalogue is more multifractal than the shallow one; (iii) the magnitudes of the deep catalogue are characterized by a right-skewed multifractal spectrum, while that of the shallow magnitude is rather symmetric; (iv) a direct relationship between the b-value of the Gutenberg–Richter law and the multifractality of the magnitudes is suggested.

1. Introduction

Earthquake sequences have been widely investigated in order to detect fractal/multifractal features in the space and time domain [1–7]. On the contrary, the investigation of the fractality/multifractality of earthquakes in magnitude domain has not been extensively approached so far. Lennartz et al. [8] analysed the long-range correlation properties in the magnitude sequences of earthquakes occurred in Northern and Southern California by using the detrended fluctuation analysis (DFA), revealing that long-term memory exists in the seismic activity manifested in the temporal fluctuations of magnitudes. Varotsos et al. [9] applied the DFA to the magnitude sequence of California seismicity between 1973 and 2003, and detected a change in the long-range temporal correlations between earthquake magnitudes from a weak persistence (DFA exponent $\sim$0.6) to anti-persistence (DFA exponent even lower than 0.5) prior the occurrence of the largest events. Aggarwal et al. [10] analysed the sequence of magnitudes of the earthquakes occurred in Kachchh area (Gujarat, Western India) from 2003 to

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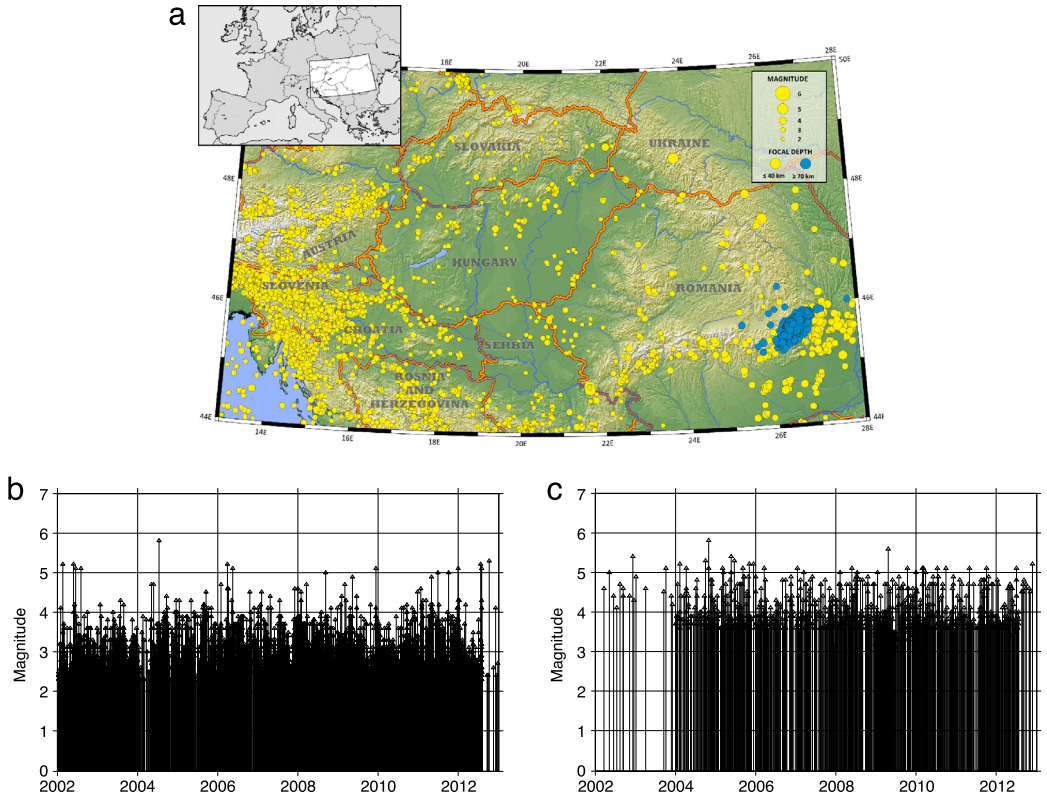

Fig. 1. (a) Spatial distribution of the Pannonia earthquakes: the shallow (depth smaller than 40 km) events are indicated by yellow circles; the deep (depth larger than 70 km) events by blue circles; (b) magnitude time series of shallow earthquakes; (c) magnitude time series of deep earthquakes. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2012, finding that the aftershock-depleted catalogue is more multifractal and also more persistent than the whole catalogue, indicating that aftershocks contribute to increase the homogeneity and the randomness of the magnitude sequence of the whole seismicity.

In this study, we investigate the magnitude sequences of earthquakes occurred in the Pannonian Basin, considering separately the shallow and the deep seismicity, whose multifractality has not been studied so far.

2. Data

The Pannonian Basin, located in northern sector of the central Mediterranean region, is bounded on the north to the east by the Carpathian mountain belt, on the south by the Dinarides mountain belt and on the west by the Eastern Alps. Recently, the area, tectonically rather complicated, has been deeply investigated [11,12].

The seismic activity in the region is less intense than that occurring in the peripheral areas; nevertheless, the analysis of the distribution of the total seismic energy release suggests that the basin is currently affected by deformation. The seismicity is shallow (earthquakes whose hypocentral depth is within the top 30–40 km of the earth's crust) in the entire region, except for the Vrancea zone where the events occur at larger depth, betweenapproximately 70 and 160 km (Fig. 1). From the analysis of the focal mechanism solutions it is deduced that strike-slip and thrust faulting are almost exclusive in the Southern Alps and in the Dinarides, and are exclusively strike-slip type in the Eastern Alps and Western Carpathians. In the Pannonian Basin, thrust and strike-slip faulting seems to dominate, but Vrancea events occur in a compressive regime with thrust tectonics [13].

The Pannonian earthquake catalogue has been compiled, comprising both historical and instrumental seismicity within a region delimited by 44.0–50.0N latitude and 13.0–28.0E longitude mainly for the seismic hazard assessment of nuclear power plant sites. A "quasi homogenous" earthquake catalogue was obtained converting the different magnitude scales into moment magnitude (Mw). The Pannonian catalogue spans from 1501 to 2012. Theapplication of the Reasenberg's [14] declustering method has eliminated from the catalogue all the aftershocks leading to an earthquake catalogue comprising "independent" events. The completeness magnitude of the Pannonian catalogue decreases with the time, being 6.0 since 1500, 5.8 since 1601, 5.3 since 1701, 4.7 since 1801 and 3.5 since 1881. These data jointly used with stress data derived from focal mechanism solutions for individual earthquakes, a relatively strong basis for evaluating seismic sources and seismotectonic models have been obtained for the area inside the Pannonian Basin and around [15].