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Application of fractal and multifractal approaches to spatiotemporal seismic-electromagnetic data to study the earthquake preparation processes

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Here we summarize our experience in application of the methods of fractal and multifractal analysis to seismotectonic and electromagnetic data. First we argue the necessity to apply fractal and multifractal approaches to geophysical data of seismic and electromagnetic origin meaning extraction of the earthquake precursory signatures. Our motivation is based on our results of destruction process modeling as well as on the SOC (self-organized critical) concept of the earthquake system dynamics. In both cases fractal spatiotemporal structures are formed in the process of the crack evolution towards the main rupture. Then we apply our techniques to study dynamics of the seismicity distribution before 12 violent earthquakes occurred in Japan and Southern California and to investigate evolution of scaling characteristics of the ULF (f=0.001-1Hz) electromagnetic emissions before strong earthquakes. Definite peculiarities in variations of the high- and low-order fractal dimensions are revealed on the earthquake preparation stage. In particular, we analyzed the dynamics of four multifractal characteristics, namely, the minimal Holder exponent αmin, the information dimension S = $\alpha 1$ = d(1), the correlation dimension d(2), and the abscissa of the top of multifractal spectrum $\alpha 0$. These multifractal characteristics provide important information on the inhomogeneity of the seismicity distribution and the level of seismicity clustering in wide range of scales. Generally, a tendency of decreasing of the multifractal characteristics αmin, S and d(2), and increasing of $\alpha 0$ has been revealed before all 12 earthquakes considered. These tendencies are especially pronounced prior to the Hyogo–ken Nanbu (Kobe) earthquake of 17 January, 1995 in Japan (M = 7.2, depth =33 km). We have also shown that the first order fractal dimension of the ULF electromagnetic time series increased before the Guam earthquake of 8 August 1993 as well as before the swarm of Japanese EQs of July-August 2000. That gives us a possibility to consider the corresponding dynamics as the EQ precursory signatures and pay a special attention to fractal approach when develop the EQ forecasting methods. In theoretical aspect, we showed how the crack network evolves from the state with random, chaotic behavior to the state with fractal, clustered distributions before the main rupture. Also we showed that propagation of the coda waves through the fractally distributed cracks leads to formation of the monoscaling power law spectrum of the scattered waves. Similarity between theoretically predicted and experimentally observed dynamics of geophysical parameters is revealed, which testifies that fractal approach to geophysical data processing is one of the promising way for monitoring the destruction processes in seismically active areas and thus for development of the earthquake forecasting methods