15th International Congress of the Geological Society of Greece
Athens, 22-24 May, 2019 | Harokopio University of Athens, Greece
Bulletin of the Geological Society of Greece, Sp. Pub. **7** Ext. Abs. GSG2019-219

Scaling Properties and Stochastic Modelling of Earthquake Time Series

G. Michas[1], F. Vallianatos[1,2]

(1) UNESCO Chair on Solid Earth Physics and Geohazards Risk Reduction, Technological Educational Institute of Crete, Chania, Greece, gmichas@hotmail.com
(2) Department of Geophysics–Geothermics, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Athens, Greece

Earthquake time series are widely used to characterize the main features of regional seismicity and to provide useful insights into the earthquake dynamics. Furthermore, the temporal properties of seismicity have important implications regarding earthquake physics and probabilistic earthquake hazard assessment studies. As such, the temporal properties of seismicity have been the subject of intensive study during the past years. Research focused on whether waiting times, i.e. the time intervals between successive earthquakes, for various threshold magnitudes and spatial scales present particular scaling properties described by "universal" distributions (e.g., Bak *et al*., 2002; Corral, 2004), the form and the physical mechanism of which are of great importance in earthquake modeling and hazard assessments. Another main research question related to this topic is whether earthquakes occur randomly in time, following a Poisson process, or they possess some kind of "memory", where the time of the next earthquake is related to the time of the previous ones.

The present work seeks to contribute in this field. We study earthquake time series from the Corinth Rift (Greece), as well as from the Southern California and Japan. In such tectonically active regions, properties such as intermittency, fractality/multifractality and non-stationary clustering are common in earthquake time series, highlighting the complex nature of the earthquake generation process (e.g., Michas *et al*., 2013; Michas *et al*., 2015; Vallianatos *et al*., 2016). The probability density function of waiting times, for various time periods, spatial scales and threshold magnitudes in all three regions, exhibits bimodality and a gradual crossover between two power-law regimes at short and long waiting times, respectively (Fig.1), suggesting that the distribution is a mixture of correlated events at short timescales, induced by aftershock sequences and earthquake swarms, and correlated background activity at long timescales. Such properties indicate clustering effects at all timescales and memory in the seismogenic process.

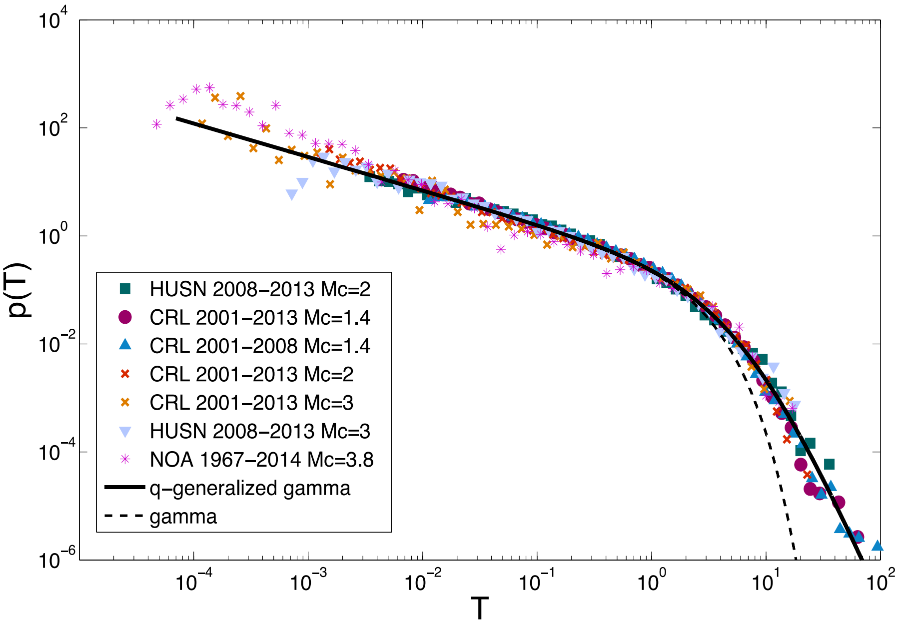

Figure 1. Probability density p(T) of the rescaled waiting times T in the Corinth Rift for various earthquake catalogues (HUSN, CRL, NOA) and for various time periods and threshold magnitudes. The solid line represents the corresponding fit according to the q-generalized gamma function, while the dashed line represents the corresponding fit according to the gamma function (from Michas, 2016).

To model this behavior, we introduce a stochastic model with memory effects that reproduces the temporal scaling behavior observed in regional seismicity (Michas & Vallianatos, 2018). For nonstationary earthquake activity, where the average seismic rate fluctuates, the solution of the stochastic model is the q-generalized gamma function that presents two power-law regimes for short and long waiting times, respectively, while for stationary activity it reduces to the standard gamma function, frequently observed in stationary earthquake timeseries (Corral, 2004). The application of the derived model to the aforementioned earthquake timeseries shows that for various threshold magnitudes and spatial areas and after rescaling with the mean waiting time, the normalized probability density functions fall onto a unique curve, which is characterized by two power-law regimes for short and long waiting times, respectively, a scaling behavior that can exactly be recovered by the derived q-generalized gamma function (Fig.1). The results seem robust for nonstationary earthquake time series, despite the possible incompleteness of the earthquake catalogs, the selected threshold magnitude, or the spatial size of the chosen area, further signifying self-similarity in the temporal structure of seismicity. The results show the validity of the stochastic model and the derived scaling function, further signifying both short- and long-term clustering effects and memory in the evolution of seismicity.

Acknowledgements

This work is supported by the project HELPOS (MIS 5002697) which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the EU.

References

Bak, P., Christensen, K., Danon, L., Scanlon, T., 2002. Unified scaling law for earthquakes. Physical Review Letters 88, 178501.

Corral, A., 2004. Long-term clustering, scaling, and universality in the temporal occurrence of earthquakes. Physical Review Letters 92, 108501.

Michas, G., 2016. Generalized statistical mechanics description of fault and earthquake populations in Corinth Rift (Greece). PhD Thesis, University College London.

Michas, G., Vallianatos, F., Sammonds, P., 2013. Non-extensivity and long-range correlations in the earthquake activity at the West Corinth rift (Greece). Nonlinear Processes in Geophysics 20, 713–724.

Michas, G., Sammonds, P., Vallianatos, F., 2015. Dynamic multifractality in earthquake time series: Insights from the Corinth rift, Greece. Pure and Applied Geophysics 172, 1909-1921.

Michas G., Vallianatos F., 2018. Stochastic modelling of non-stationary earthquake time series with long-term clustering effects. Physical Review E 98, 042107.

Vallianatos F., Papadakis G., Michas G., 2016. Generalized statistical mechanics approaches to earthquakes and tectonics. Proc. R. Soc. A 472, 20160497.