

TEMPORAL VARIATIONS OF SEISMICITY FROM THE APPLICATION OF TSALLIS ENTROPY

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The concept has recently taken hold that Earth’s crust behaves as a complex, non-linear dynamic system characterized by long-range correlations (Bowman *et al.*, 2008, and references therein). In statistical seismology these features make some of the classical methods of analysis unsuitable. The Boltzmann-Gibbs (BG) entropy is appropriate to study systems where the elements interact locally in space and time while, if the interactions are long-range, new entropies that generalize some of the properties of BG entropy are more suitable. In this respect, Tsallis (1988) introduced a non-additive entropy that has proved useful for applications in many fields, from physics to chemistry, medicine, informatics, linguistics, economics, seismology.

We derive the probability distribution of the magnitude by maximizing a non-extensive generalization of the Boltzmann–Gibbs entropy given by the Tsallis entropy (Rotondi *et al.*, 2022). The shape parameter q of this distribution is called the entropic index and is found to characterize the subadditive ($q>1$) and superadditive ($q<1$) regimes.

Two active seismogenic areas in central Italy are analyzed, the former including the L’Aquila sequence occurred in 2009 and the latter the Amatrice-Norcia sequence occurred in 2016. Parameter estimation is performed by following the Bayesian approach in order to exploit prior knowledge on the phenomenon, e.g. that provided by Vallianatos *et al.* (2016).

To analyse in detail the variations of the q index and the entropy, we estimate these for time windows of a fixed number of events that shift at each new event. Both the q index and the Tsallis entropy show significant and lasting decreases before the first strong earthquake in the sequences, and sudden increases after them. This indicates that these quantities can be considered as indicators of the level of concentration of energy, and hence of the activation state of the systems. Further studies on different cases and seismotectonic settings are needed to test and consolidate the results.

References

- Bowman D.D., Ouillon G., Sammis C.G., Sornette A. and Sornette D.; 1998: *An observational test of the critical earthquake concept*, J. Geophys. Res., **103**, 24359-24372.
- Rotondi R., Bressan G. and Varini E.; 2022: *Analysis of temporal variations of seismicity through non-extensive statistical physics*, Geophys. J. Int., **230**, 1318-1337.
- Tsallis C.; 1988: *Possible generalization of Boltzmann-Gibbs mechanics*. J. Stat. Phys., **52**, 479-487.
- Vallianatos F., Papadakis G. and Michas G.; 2016: *Generalized statistical mechanics approaches to earthquakes and tectonics*, Proc. R. Soc. A, **472**, 20160497.