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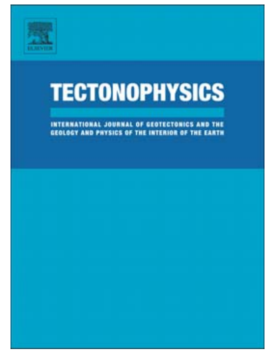

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Time-series analysis of earthquake sequences by means of information recognizer

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Three seismic sequences of several thousand earthquakes each are analyzed by means of a tunable information recognizer known as wlzip. These sequences are different both in the geographical coverage and the time span, including earthquakes of magnitude larger than 8.0. The main variable under scrutiny here is the time interval between consecutive events. Two parameters (mutability and interval dilation) are defined for each sequence, which relate to the information contained in it. In this way it is possible to characterize different regimes in the seismic activity. For instance, mutability increases before large earthquakes and decreases sharply immediately after each of these events. On the other hand, interval dilation reaches a clear maximum several months before major earthquakes, while it decreases to its lowest possible value after such earthquakes during the aftershock regime. Extensions of the application of this new method to other problems in seismicity are mentioned.

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INTRODUCTION

Tools from the study of complex systems have been useful in the analysis of seismicity [1–7]. Features such as self-similarity, self-organization, patterns, finite-scaling, spatial distribution, and scale-free characteristics have been studied in this context. In particular, various ways to study the time sequence of earthquakes have been investigated (*e.g.* [8–13]). On the other hand, seismic hazard is an interesting and important topic of study, which has been dealt with in various ways [14, 15]. New tools can contribute significantly to the understanding of earthquake dynamics, and the purpose of this paper is to suggest an information theory approach to the study of seismicity.

In this sense, one approach has been to focus on the time interval between earthquakes [16–22]. Various features have been studied, such as the statistical properties of the "calm periods", where a scale-free time distribution can be found [16], or the time interval between major events, either for models of seismicity [17] or for seismic catalogs [18, 20–22]. One of the most studied methods to analyze complex time series, and seismic time series in particular, is "natural time". This method involves a reparametrization of time, and can be applied to a number of complex time series arising in various physical and geophysical systems [20, 23–25]. For earthquakes, this method has been applied to precursor seismic electric signals by the definition of a *natural time* for the occurrence of the kth event in the time series, namely $\chi_k = k/N$, where N is the number of data. The method of natural time considers the time evolution of the pair (χ_k, E_k), where E_k is the energy released during that event, and it has been shown that the variance of χ for the seismic electrical signals decreases when a mainshock is about to occur [18, 19, 26]. We propose in this paper a different way to analize the time interval between two seismic events, by using information theory.

Very recently a data analysis method based on information recognition in any time series has yielded useful results on magnetic phase transitions [27, 28], agitation in stock markets [29], variations in capitalizations towards pensions [30], blood pressure [31], and wind energy [32]. In the present paper we apply this powerful technique to the recognition of information of seismological activity. Our results suggest that an indicator can be defined, which begins to increase several months prior to important earthquakes.

The following are the main novel features considered in the present paper. Seismic data from geographical regions around the epicenter of important earthquakes are considered on extended time bases, both before and after these earthquakes. The method based on information theory is invoked to calculate the mutability (a way of variability defined below) of the time series associated to the time interval between consecutive quakes over a predetermined magnitude in the Richter scale. Based on this, an indicator called *interval dilation* or simply *dilation* is constructed. Dilation maximizes over a critical value several months before earthquakes of magnitude about 7.0 or higher. No false overshoots for dilation have been found for periods of lower seismic intensity. Since the behavior is the same for three different geographical areas in different periods of time, we believe this methodology establishes a new way to detect areas where seismic energy can be accumulating.