

# 1 Statistical characteristics of non-volcanic tremor distributions along the Mexican 2 Subduction Zone

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## 12 **Abstract.**

13 We analyze the statistical characteristics of non-volcanic tremor (NVT) sequences in the Mexican  
14 subduction zone. To this end, we employ various techniques, including the Gutenberg–Richter  
15 relationship, non-extensive statistics, and multifractal detrended moving-average analysis, to extract  
16 information on magnitude and interevent-time distributions. The  $b$ -value results reveal that  $b$  ranges  
17 from 1.25 to 2.42, with the highest values occurring in the down-dip portion of the plate interface. In  
18 contrast, the  $q$ -value shows an inverse behavior, reaching its highest values in the interplate coupling  
19 region. Similar to tectonic earthquakes, NVT sequences exhibit a multifractal structure in both  
20 magnitude and interevent-time series. The multifractality analysis suggests that this behavior is  
21 associated with long-term correlations, the probability distribution of the data, and nonlinear dynamics.  
22 Both apparent and intrinsic multifractality are identified, with the former being dominant. Our  
23 estimates of the Hurst exponent ( $H$ ) range from 0.65 to 1.06; most sequences indicate strong  
24 persistence ( $H > 0.95$ ), while values exceeding unity suggest a transition toward non-stationary  
25 behavior. These high temporal correlations may reflect localized fluid-perturbed regions, although this  
26 interpretation remains speculative. Regarding the distribution that best describes interevent sequences,  
27 we find that most sequences are well described by a Lognormal distribution and, to a lesser extent, by a  
28 Gamma distribution. Finally, observations of tectonic tremor duration exhibit substantial scatter,

1 resulting in low coefficients of determination in scaling relationships. The source of this variability may  
2 be related to the NVT generation mechanism or to detection and characterization processes.

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4 **Keywords** Non-volcanic tremor, *b*-value, non-extensive statistics, multifractality, Mexico

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## 6 **1 Introduction**

7 Non-volcanic tremor (NVT) is an enigmatic seismic phenomenon that has become a topic of increasing  
8 interest, particularly in subduction zones. NVTs are emergent seismic signals of long duration and low  
9 amplitude (Obara, 2002). Previous studies have shown that NVTs are composed of repeating small  
10 low-frequency earthquakes, commonly accompanied by very-low-frequency earthquakes that, in both  
11 cases, involve shear failure and slip (Shelly et al., 2007; Bostock et al., 2015; Gomberg et al., 2016a, b).  
12 NVTs mainly occur along the plate interface, close to the shallow and deep edges of locked regions.  
13 This phenomenon can also be observed in other tectonic environments, such as in convergent margins  
14 (e.g., Taiwan; Tang et al., 2010) and continental transform faults (e.g., California; Nadeau and Dolenc,  
15 2005; Shelly, 2010). Fluids are implicated in generating NVTs, similar to volcanic tremor processes  
16 (Obara, 2002). Pressure and temperature conditions in subduction zones, together with dehydration  
17 processes, control the occurrence of NVT (Yoshioka et al., 2008; Peacock, 2009). It has been reported  
18 that NVTs occur in regions of high pore-fluid pressure (Shelly et al., 2006). Other factors also  
19 contribute, including the composition of the overriding plate and processes such as metamorphism of  
20 subducting seamounts (Wada et al., 2008). Non-volcanic tremors commonly exhibit episodic activity,  
21 with periods of intense activity lasting from days to weeks, separated by quiescent intervals of months  
22 with few or no events (Obara, 2002). NVTs are also closely associated with slow earthquakes, with  
23 both phenomena sharing temporal and spatial occurrence (Rogers and Dragert, 2003). Another  
24 important feature of NVTs is their ability to be triggered by large earthquakes, such as the 2002 Denali

1 earthquake ( $M_w = 7.8$ ) in Alaska (Rubinstein et al., 2007) and the 2003 Tokachi-oki earthquake ( $M_w =$   
2 8.1) in Japan (Miyazawa and Mori, 2005), both of which triggered enhanced NVT activity.

3

4 Tectonic tremors have been reported along the Middle America Trench in Mexico, in the states of  
5 Guerrero (Payero et al., 2008; Cruz-Atienza et al., 2015; Villafuerte and Cruz-Atienza, 2017; Husker et  
6 al., 2019; Plata-Martínez et al., 2021; Chen et al., 2025), Jalisco-Colima (Ide, 2012), and Oaxaca  
7 (Brudzinski et al., 2010; Husker et al., 2019). In Guerrero, NVTs have been detected at approximately  
8 200 km downdip, at depths of 40-50 km, and closer to the trench, at depths of 10-16 km (Plata-  
9 Martínez et al., 2021; Chen et al., 2025). Similarly, in Oaxaca, NVTs are located about 150-200 km  
10 from the trench at depths of 30-50 km (Brudzinski et al., 2010). In Western Mexico, NVTs occur in a  
11 narrow band oriented parallel to the trench, mostly at depths of 30-50 km (Ide, 2012). Much of the  
12 research on tectonic tremors has focused on locating events, generating catalogs, and their tectonic  
13 interpretation. Fewer studies, however, have examined the statistical characteristics of event  
14 occurrence. For example, Kao et al. (2010) determined the  $b$ -value of NVT sequences in northern  
15 Cascadia ( $M_w \sim 1.0 - 1.7$ ), finding that the  $b$ -value of  $\sim 1$ . Staudenmaier et al. (2019) estimated the  $b$ -  
16 value of NVTs in the San Andreas Fault ( $0.44 < M_w < 2.7$ ), obtaining a  $b$ -value of 2.52. In contrast,  
17 other studies reported extremely high  $b$ -values ( $b > 5$  with  $1.5 < M_w < 2.7$ ;  $b = 4.2$  with  $0.3 < M_w < 1.5$ )  
18 (Sweet et al., 2014; Bostock et al., 2015). In this article, we studied the statistical features of NVT  
19 sequences generated at the Mexican subduction zone. We analyzed the Gutenberg-Richter relationship,  
20 non-extensive statistics, and multifractality of magnitude and interevent-time distributions. Our results  
21 provide detailed statistical characterization of NVTs in subduction zones, which may contribute to a  
22 better understanding of their generation mechanisms.

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24

## 1 **2 Tectonic setting**

2 The Mexican subduction zone (MSZ) is located along the border of three tectonic plates: the Cocos  
3 (CO), North American (NA), and Rivera (RI) plates, respectively (Fig. 1). Convergence rates predicted  
4 from the NUVEL1-A model (DeMets et al., 1994) fluctuate from 2.0 to 6.8 cm/yr for the RI-NA  
5 convergence in the north (Jalisco-Colima) to the CO-NA convergence in the south (Oaxaca),  
6 respectively (Fig. 1). The rupture areas of the previous largest earthquakes exhibit a seismic gap in the  
7 MSZ, known as the Guerrero seismic gap (GG). The GG is a 200 km long segment in the CO-NA plate  
8 boundary (Fig. 1). The gap is capable of producing an earthquake with a magnitude of 8.1-8.4 if the  
9 entire gap were ruptured in a single event (Singh and Mortera, 1991). The gap has not experienced a  
10 significant event ( $M > 7$ ) since 1911. The geometry of the subducted slab varies from north to south. In  
11 the Jalisco region, the RI plate subducts at a steep angle ( $\sim 50^\circ$ ), and then the dip angle of the CO plate  
12 decreases gradually toward the southeast. In the Gurrero-Oaxaca region, the subducted slab is almost  
13 subhorizontal (Pardo and Suárez, 1995; Pérez-Campos et al., 2008). As mentioned above, non-volcanic  
14 tremors occur at certain regions within the subduction zone regime. They appear to signal the transition  
15 from creep to locking trench parallel segments (Chen et al., 2025).

16

## 17 **3 Data and methods**

### 18 **3.1 Data**

19 We retrieved non-volcanic tremor catalogs for six sequences along the Mexican subduction zone, as  
20 reported in previous studies (Ide, 2012; Idehara et al., 2014; Husker et al., 2019; Plata-Martínez et al.,  
21 2021; Chen et al., 2025). We studied NVT events occurring from 2005 to 2019 with hypocentral depths  
22 less than 50 km and magnitudes ranging from -0.8 to 3.65 (Table 1). Sequences 1, 3, and 4 occurred  
23 downdip of the coupling plate interface in the Guerrero segment, while sequences 5 and 6 took place at  
24 the coupling plate interface of the same segment. Sequence 2 was located further west, at the boundary

1 between the subduction regimes of the Rivera and Cocos plates (Fig. 2). Catalogs for sequences 1-3 are  
2 available through the World Tremor Database (see the Data Availability section). The information  
3 reported in these catalogs includes origin time, hypocentral location, moment magnitude ( $M_w$ ), and  
4 event duration for sequences 1-3 and 5. For sequence 4, locations were obtained using a single local  
5 seismic station, providing only origin time and hypocentral location. Similarly, sequence 6 does not  
6 report magnitudes. In this case, Chen et al. (2025) used an algorithm based on envelope correlation and  
7 matched filtering, providing location, duration, and average seismic energy rate instead of magnitude.  
8 Although magnitudes are unavailable for sequences 4 and 6, these catalogs provide sufficient  
9 information to analyze interevent times. Because NVTs often consist of superimposed low-frequency  
10 earthquakes (LFEs) of low amplitude, some studies prefer to use average energy or the root-mean-  
11 square (RMS) amplitude as a proxy for seismic energy. Hypocenters of NVTs were located in the states  
12 of Guerrero and Jalisco and were detected primarily using temporary seismic networks (sequences 1, 2,  
13 3, 5, and 6). These networks include: the Mesoamerican Subduction Experiment (MASE, 2004–2007),  
14 Mapping the Rivera Subduction Zone (MARS, 2006–2007), and the Guerrero Seismic Gap project (G-  
15 GAP, 2009–2014).

16

## 17 **3.2 Methods**

### 18 **3.2.1 Estimation of the $b$ -value**

19 The earthquake frequency-magnitude distribution (FMD) is commonly described by the Gutenberg-  
20 Richter law (Gutenberg and Richter, 1944):

21

$$22 \quad \log_{10} N(M) = a + bM \quad , \quad (1)$$

23

24 where  $N$  is the number of earthquakes  $\geq M$  above the magnitude of completeness ( $M_c$ ),  $a$  and  $b$  are

1 constants that describe the earthquake productivity and the proportion of small to large events,  
2 respectively. Globally, the  $b$ -value is about one on average (Lay and Wallace, 1995). Fluctuations from  
3 this value are due to several factors, such as fluid pressure (Henderson et al., 1994), heterogeneity in  
4 the fault zone (Mogi, 1963), thermal gradient (Warren and Latham, 1970), and variations in the state of  
5 stress (Schorlemmer et al., 2005; Scholz, 2015). The  $b$ -value is determined using the maximum  
6 likelihood method proposed by Aki (1965). The equation that describes this estimator is the following

$$7 \quad b = \frac{\log_{10} e}{\bar{M} - (M_c - \Delta M / 2)} \quad , \quad (2)$$

8  
9  
10 where  $M_c$  is the catalog completeness magnitude,  $\bar{M}$  is the average magnitude with a magnitude  
11 greater than  $M_c$ , and  $\Delta M$  is the magnitude binning interval.  $M_c$  was estimated using the maximum  
12 curvature method (Woessner and Wiemer, 2005). We determined  $b$ -values for NVT sequences with  
13 reported magnitudes (sequences 1-3 and 5), and the results are shown in Fig. 3 and Table 2. Following  
14 Woessner and Wiemer (2005), we also used a bootstrap approach to estimate uncertainties in the  $b$ -  
15 value and  $M_c$ .

### 16 17 **3.2.2 Non-extensive statistical analysis**

18 Non-extensive statistical mechanics (NESM) provides a theoretical framework for analyzing non-  
19 equilibrium complex systems, including earthquake phenomena. For systems exhibiting long-range  
20 correlations, memory effects, or fractal characteristics, NESM offers a particularly suitable  
21 mathematical approach (Tsallis, 2009). Within this context, Sotolongo-Costa and Posadas (2004)  
22 proposed the fragment asperity model, in which the release of seismic energy ( $\epsilon$ ) is linked to the size of  
23  $r$  fragments that occupy the space between irregular fault interfaces. Silva et al. (2006) used a

1 volumetric relationship between seismic energy and fragment size in the form of  $\varepsilon \propto r^3$ , under this  
 2 assumption, the cumulative distribution of the number of earthquakes  $N$  with a magnitude greater than  
 3  $M$  is

$$5 \quad \log \frac{N > M}{N} = \frac{(2-q)}{(1-q)} \log \left[ 1 - \left( \frac{1-q}{2-q} \right) \left( \frac{10^{2M}}{a_s^{[2/3]}} \right) \right], \quad (3)$$

6  
 7 where the  $q$ -value is in the range of  $1 < q < 2$ , the constant  $a_s$  is a proportionality parameter between the  
 8 released seismic energy and the fragment size. The  $q$ -value quantifies the length scale of spatial  
 9 interactions; a  $q$ -value of  $\sim 1$  corresponds to short-range correlations, while increasing  $q$  indicates that  
 10 the physical state becomes progressively more unstable. High  $q$ -values suggest that the fault planes are  
 11 out of equilibrium, implying a higher likelihood of subsequent events (Sotolongo-Costa and Posadas,  
 12 2004). In most tectonic regimes,  $q$  typically ranges from 1.5 to 1.7 (Sarlis et al., 2010). We calculated  
 13 the  $q$ -values for all NVT sequences with reported magnitudes. As in the case of  $b$ -values, we employed  
 14 bootstrap resampling to quantify uncertainties in  $q$ . The results are presented in Fig. 4 and Table 3.

### 16 3.2.3 Multifractal detrended moving average analysis

17 The multifractal detrended fluctuation analysis (MFDFA) is a technique used to quantify the scaling  
 18 behavior and correlations in time series (Kantelhardt et al., 2002). In seismology, MFDFA has shown  
 19 that seismicity exhibits multifractal behavior, reflecting the nonlinear dynamics of tectonic processes  
 20 (Telesca and Lapenna, 2006). The method has been applied to track the evolution of multifractal  
 21 parameters across different stages of seismic activity (Monterrubio-Velasco et al., 2020) and in long-  
 22 term regional studies (Alam et al., 2023), illustrating its ability to explore the organization and  
 23 variability of seismic events. An improvement to MFDFA, the multifractal detrended moving average

1 analysis (MFDMA), was proposed by Gu and Zhou (2010), providing enhanced robustness to trends  
 2 and non-stationarities in the data. In this study, we employ MFDMA to investigate the multifractal  
 3 properties of both interevent times and magnitude distributions of NVT sequences, allowing us to  
 4 characterize apparent and intrinsic multifractality. We summarize the MFDMA algorithm of Gu and  
 5 Zhou (2010) as follows. First, a cumulative time series of a given physical parameter  $D(t)$  is  
 6 constructed and represented as

$$7 \quad y(t) = \sum_{i=1}^t D(i) \quad , \quad (4)$$

9  
 10 where  $t = 1, 2, 3, \dots, N$  (length of the time series) and  $D(i)$  is the observed time series. Then, a moving  
 11 average function of  $y(t)$  is calculated in a moving window as

$$12 \quad \tilde{y} = \frac{1}{s} \sum_{k=-\lfloor (s-1)\theta \rfloor}^{\lfloor (s-1)(1-\theta) \rfloor} y(t-k) \quad , \quad (5)$$

14  
 15 where  $s$  is the window size. Here,  $\lfloor x \rfloor$  denotes the floor function (the largest integer less than or  
 16 equal to  $x$ ), while  $\lceil x \rceil$  represents the ceiling function (the smallest integer greater than or equal to  $x$ ).  
 17 The position parameter  $\theta$ , describes the delay between the moving average function and the original  
 18 time series ( $0 < \theta < 1$ ). For example, if  $\theta = 0, 0.5$ , and  $1$ , it describes a backward, centered, and forward  
 19 moving average, respectively.

20  
 21 Afterwards, the residual sequences are obtained by detrending the time series through removing the  
 22 average function,  $\tilde{y}(i)$ , resulting in

1

$$\epsilon(i) = y(i) - \tilde{y}(i) , \quad (6)$$

3

4 where  $s \leq i \leq N$ . The residual series ( $\epsilon(i)$ ) is divided into  $N_s$  disjoint segments with the same size of  
 5  $s$ , where  $N_s = N/s - 1$ . The residual sequence for each segment is denoted by  $\epsilon_v$ , where

$$\epsilon_v(i) = \epsilon(l+i) \text{ for } 1 \leq i \leq s \text{ and } l = (v-1)s . \text{ Then we calculate the root-mean-square fluctuation}$$

7 function ( $F_v(s)$ ) for a segment of size  $s$  as follows

8

$$F_v(s) = \left( \frac{1}{s} \sum_{i=1}^s \epsilon_v^2(i) \right)^{1/2} . \quad (7)$$

10

11 The  $q$ -th order fluctuation function ( $F_q(s)$ ) is obtained by

12

$$F_q(s) = \left( \frac{1}{N_s} \sum_{v=1}^{N_s} F_v^q(s) \right)^{1/q} , \quad (8)$$

14

15 for all  $q \neq 0$ . For the case of  $q = 0$ , we have

16

$$\ln[F_0(n)] = \frac{1}{N_n} \sum_{v=1}^{N_n} \ln[F_v(s)] , \quad (9)$$

18

19 where the scaling behavior of  $F_q(s)$  follows the relation that is given by  $F_q(s) \sim s^{h(q)}$  where  $h(q)$  is the

20 Holder exponent or generalized Hurst exponent. The multifractal scaling exponent is calculated by

21

$$1 \quad \tau(q) = qh(q) - 1 \quad . \quad (10)$$

2

3 Finally, the singularity strength function ( $\alpha(q)$ ) and the multifractal spectrum ( $f(\alpha)$ ) can be obtained as

4

$$5 \quad \alpha(q) = \frac{d\tau(q)}{dq} \quad , \quad (11)$$

6

7 and

8

$$9 \quad f(\alpha) = q\alpha - \tau(q) \quad , \quad (12)$$

10

11 respectively. In the multifractal analysis of sequences 1 to 4, we used the following input parameters:  $N$   
 12  $= 30$ ,  $\theta = 0$ ,  $q \in [-5, 5]$  with  $q$  increments of 0.2, the lower bound of segment size  $s$  is fixed to 10,  
 13 while the upper bound is given by  $N/10$ , as recommended by Gu and Zhou (2010). In the case of  
 14 sequences 4 and 5, the upper bound of segment size  $s$  is set to  $N/4$  because they have less data than the  
 15 other sequences. The parameters adopted ensure methodological consistency. The choice of  $N$  provides  
 16 sufficient scale for local trend estimation, balancing statistical reliability in short series with detailed  
 17 detrending in longer ones.  $\theta = 0$  corresponds to a backward-moving average, preserving causality,  
 18 while the  $q$  range probes multifractal behavior across fluctuation magnitudes and maintains numerical  
 19 stability. This configuration enables robust, consistent scaling analysis across datasets of varying  
 20 lengths. Results for  $F_q(s)$ ,  $h(q)$ ,  $\tau(q)$ ,  $\alpha(q)$ , and  $f(\alpha)$  for interevent time and magnitude distributions are  
 21 shown in Figs. 5 and 6 and Figs. 7 to 9, respectively. In the MF DFA framework,  $q$  is the fluctuation  
 22 order and is used to scan different fluctuation scales. In contrast, in the context of non-extensive  
 23 statistical mechanics, the non-extensive parameter ( $q$ -value) quantifies non-additivity and entropy.

1

### 2 **3.2.4 Multifractal parameters**

3 We determined multifractal parameters using the equations presented in the previous section, following  
4 De Freitas and França (2024). We start with the degree of asymmetry ( $A$ ), defined as

5

$$6 \quad A = \frac{\alpha_{max} - \alpha_0}{\alpha_0 - \alpha_{min}} , \quad (13)$$

7

8 where  $\alpha_0$  is the value for which  $f(\alpha)$  is maximum. If  $A = 1$ ,  $f(\alpha)$  is symmetric. On the contrary, when  $A >$   
9  $1$ , the symmetry is right-skewed, and if  $0 < A < 1$ , the symmetry is left-skewed. The values of  $\alpha_{max}$  and  
10  $\alpha_{min}$  represent the extreme values of the singularity exponent and are related to the minimum and  
11 maximum fluctuation of the signal. The degree of multifractality ( $\Delta\alpha$ ), which is determined by

12

$$13 \quad \Delta\alpha = \alpha_{max} - \alpha_{min} . \quad (14)$$

14

15 A low value of  $\Delta\alpha$  denotes that the time series is close to fractal. On the other hand, a high value of  $\Delta\alpha$   
16 indicates that the multifractal strength is higher (De Freitas and De Medeiros, 2009). The singularity  
17 parameter ( $\Delta f$ ) describes the broadness of the singularity spectrum and is defined as

18

$$19 \quad \Delta f = f(\alpha_{max}) - f(\alpha_{min}) . \quad (15)$$

20

21 In the case that  $\Delta f > 1$ , the left-hand side is less deep, while if  $\Delta f = 0$ , both depths of the tails are equal.  
22 According to Ihlen (2012), a long left tail indicates that the singularities are stronger (many large  
23 fluctuations/more abrupt behavior). In contrast, a long right tail indicates that the singularities are

1 weaker (smoother signal with smaller variations). The Hurst index ( $H$ ) can be obtained from the  
2 multifractal spectrum through the second-order generalized Hurst exponent  $h(q = 2)$ . If  $H > 0.5$ , it  
3 indicates persistence in long-range correlation, while  $H \approx 0.5$  shows a random character of the series  
4 (past and future fluctuations are uncorrelated or Brownian motion). On the other hand,  $H < 0.5$  reflects  
5 anti-persistence. In this case, the fluctuations tend not to continue in the same direction, but instead turn  
6 back on themselves, resulting in a less smooth time series (Hampson and Mallen, 2011).

7

### 8 **3.2.5 Sources of multifractality**

9 Multifractality can be classified into two categories: apparent and intrinsic. The former type refers to  
10 the multifractality that arises from spurious or artifactual patterns, while the latter refers to a genuine  
11 origin derived from nonlinear processes within the data (Saichev and Sornette, 2006). The  
12 differentiation between apparent and intrinsic multifractality is crucial for understanding the underlying  
13 processes in a time series (Jiang et al., 2019). On the other hand, there are three primary sources for  
14 multifractality in time series: 1) the non-Gaussian distribution of innovations, 2) linear long-range  
15 correlations, and 3) nonlinear long-range correlations (Jiang et al., 2019; Wang, 2023). Two methods  
16 are commonly used to investigate these sources of multifractality: namely, the shuffling (Kantelhardt et  
17 al., 2002) and the surrogating (Theiler et al., 1992) procedures. These methods involve modifying the  
18 original sample to eliminate specific sources of multifractality. The first source (non-Gaussian  
19 distribution) is typically examined using shuffled time series. The random shuffling of a time series  
20 removes both linear and nonlinear temporal correlations (which may contribute to the scaling of  $F_q$ )  
21 while preserving the probability distribution (PDF) (Kantelhardt, 2009). Thus, if  $F_q$  from the shuffled  
22 series scales in the same way as that of the original series, one may infer that the scaling is primarily  
23 due to the probability distribution of the data. Conversely, if the shuffled series exhibits weaker  
24 multifractality compared to the original data, then multifractality likely arises from a combination of

1 temporal correlations and the PDF. Consequently, if no multifractal features remain after performing  
2 the shuffling procedure, it can be interpreted that long-range correlations are the dominant source of  
3 multifractality in the original series.

4

5 The surrogate time series method generates time series via a Fourier transform, preserving amplitudes  
6 while randomizing the phases, and then applying an inverse Fourier transform. In this form, non-  
7 linearities in the series are removed while preserving long-range correlations. The iterated amplitude-  
8 adjusted Fourier transform (IAAFT) algorithm (Schreiber and Schmitz, 1996; 2000) is appropriate for  
9 this purpose. Using the surrogate series, we performed statistical tests for  $h(q)$ ,  $\tau(q)$ ,  $\alpha(q)$ , and  $f(\alpha)$  to  
10 determine the presence or absence of intrinsic multifractality in the data. Specifically, the tests evaluate  
11 whether each indicator computed from the original series is greater than its counterpart derived from  
12 the IAAFT series. In other words, we calculate the probability that  $x$  is smaller than  $x_{IAAFT}$  ( $p$ -value =  
13  $\Pr(x < x_{IAAFT})$ ), where  $x$  is a multifractal indicator, as proposed by Wang et al. (2023). Wang et al.  
14 (2023) also stated that if the  $p$ -value is smaller than a significance level (usually 5%), then we can  
15 reject the hypothesis that the original time series is monofractal. Low  $p$ -values further suggest that the  
16 original time series exhibits intrinsic multifractality beyond fat-tailed distributions and linear long-  
17 range correlations. Alternatively, high  $p$ -values suggest the absence of intrinsic multifractality (De  
18 Freitas and França, 2024). Here, we applied MF DFA to the magnitude and interevent time series of  
19 NVT. In both cases, we generated 100 shuffled and IAAFT surrogate time series, and computed the  
20 multifractal indicators to analyze the source of multifractality. Surrogate data were used specifically  
21 used to assess the presence of intrinsic multifractality. The results are presented in Figs. 5 to 9 and  
22 Table 4.

23

24

### 1 3.2.6 Interevent-time distribution and duration scaling

2 Several interevent-time distributions have been proposed in the literature to explain earthquake  
3 interevent-time behavior (e.g., Gamma, Exponential, Lognormal, Weibull) (Corral, 2006; Davidsen and  
4 Kwiatek, 2013). We fitted interevent time data from all the NVT sequences, considering the previously  
5 mentioned statistical distributions, using the maximum likelihood estimation (MLE) method as  
6 described by Mesimeri et al. (2019). To determine the goodness of fit, we applied the Kolmogorov-  
7 Smirnov (KS) test. The Akaike and Bayesian information criteria (AIC and BIC, respectively) were  
8 also calculated to assess the relative quality of the statistical models. The best-fitting distribution is the  
9 one with the lowest AIC and BIC values. The obtained interevent-time probability distributions are  
10 shown in Fig. 10 and Table 5. Additionally, we determined scaling relationships between tremor  
11 duration and magnitude for sequences 1 to 3 and 5. The obtained scaling relations have the following  
12 form:

$$14 \quad \log(\tau) = \alpha M_w + \beta, \quad (16)$$

15  
16 where  $\tau$  is the duration of the NVT,  $M_w$  is the moment magnitude, and  $\alpha$  and  $\beta$  are constants. We  
17 present the estimated scaling relationships in Fig. 11 and Table 5.

## 18 19 4 Results

20 Our estimates of the  $b$ -value showed that the  $b$ -values for NVTs at the Mexican subduction zone range  
21 from 1.25 to 2.42, with completeness magnitudes ( $M_c$ ) between 1.10 and 1.80. Sequences 1 and 3 have  
22 the highest  $b$ -values, indicating a possible distinct characteristic of the down-dip Guerrero segment of  
23 the Cocos plate. They are followed by sequence 2, located at the interface between the Rivera and  
24 Cocos plates. The lowest  $b$ -value is found for sequence 5 in the Guerrero Gap region (Fig. 2 and Table

2), which unfortunately cannot be corroborated by sequence 6 at the same region, as it does not include magnitude data. The  $q$ -value from the non-extensive statistical analysis fluctuates from 1.39 to 1.65. The  $q$ -values show an apparent inverse relationship with the  $b$ -value, since the sequences located near the trench (2 and 5) have higher  $q$ -values than those located down-dip (1 and 3), which exhibit similar  $q$ -values. Bootstrap resampling (1000 iterations) was used to estimate uncertainties in  $b$ -values,  $M_c$ , and  $q$ -values (Tables 2 and 3). Smaller sequences (e.g., sequence 5,  $N = 101$ ) exhibit larger relative uncertainties, which are now explicitly reported. A Monte Carlo analysis incorporating these uncertainties confirms a strong negative correlation between  $b$ - and  $q$ -values, with mean Pearson coefficient  $r = -0.94$  (95% CI: -0.999 to -0.743), supporting the inverse relationship observed across the NVT sequences.

Multifractal indicators of the original time series show that the multifractal spectra are mostly right-skewed (magnitude sequences 1 to 4, interevent time sequences 1, 2, and 6). In contrast, left-skewed spectra correspond to interevent time sequences 3 and 4. Sequence 5 exhibits a symmetric multifractal spectrum. Results for the degree of multifractality ( $\Delta\alpha$ ) indicate that interevent time series have a higher multifractal strength than magnitude time series. On the other hand, the singularity parameter ( $\Delta f$ ) indicates that the singularities are weaker for magnitude sequences 2 and 3, as well as interevent time sequences 1-2 and 6. Conversely, the singularities are stronger for interevent time sequences 3 and 4. Estimates of the Hurst exponent ( $H$ ) depict a long-term persistence signature ( $H > 0.5$ ). By comparing the multifractal spectra ( $Fq(s)$ ,  $h(q)$ ,  $\tau(q)$ ,  $\alpha(q)$ , and  $f(\alpha)$ ) obtained from the original, shuffled, and surrogate time series, we observe that multifractality is not completely removed in all cases. However, in several sequences, the multifractal indicators become statistically indistinguishable from those derived from surrogate data. Statistical tests based on IAAFT surrogates show that  $p$ -values associated with the multifractal indicators ( $A$ ,  $\Delta\alpha$ ,  $\Delta f$ , and  $H$ ) vary significantly across sequences.

1 Magnitude sequence 5 and interevent time sequences 1, 4, and 5 exhibit relatively high  $p$ -values,  
2 indicating no statistically significant differences with respect to surrogate data. In contrast, magnitude  
3 sequence 1 shows consistently low  $p$ -values across multiple indicators, suggesting statistically  
4 significant deviations from surrogate behavior. For the interevent time sequences 2, 3, and 6, low  $p$ -  
5 values are observed for key parameters, such as  $\Delta\alpha$ , and, in sequence 3, for  $H$  as well, indicating  
6 significant differences relative to the surrogate series. In magnitude sequences 2 and 3, the results are  
7 mixed: some indicators yield low  $p$ -values, while others remain high, preventing a clear classification  
8 based solely on the statistical tests. Overall, the results indicate that the statistical significance of  
9 multifractality varies across sequences and depends on the specific indicator considered.

10

11 Regarding the inter-event time distributions, a comparison of the fitted probability density functions  
12 (PDFs) with the empirical distributions from sequences 1 to 4 showed that the Lognormal distribution  
13 provided the best fit. In contrast, for sequences 5 and 6, the Gamma distribution yielded the best fit for  
14 the interevent time data. In all cases, the least well-fitting distribution is the Exponential distribution  
15 (Fig. 10 and Table 5). Finally, event duration observations exhibit large scatter, resulting in linear  
16 scaling relationships with low coefficients of determination ( $0.03 < R^2 < 0.34$ ) (Fig. 11 and Table 6).  
17 This scatter is intrinsic to the genesis of NVTs or is associated with the detection process, as it is  
18 present in all reported sequences.

19

## 20 **5 Discussion**

21 We start the discussion by comparing our  $b$ -value estimates with previous studies. The  $b$ -value  
22 associated with NVTs has been determined in both crustal and subduction environments, with the latter  
23 being the most common. In crustal regions, for example, along the San Andreas Fault (Parkfield  
24 segment), Staudenmaier et al. (2019) calculated a  $b$ -value of 2.52 for NVT episodes. For subduction

1 zones, it has been found that the  $b$ -value of NVTs ranges between 1 and 5 (Kao et al., 2010; Rabbel et  
2 al., 2011; Gallego et al., 2013; Sweet et al., 2014; Bostock et al., 2015). The Cascadia subduction zone,  
3 particularly in Vancouver Island, exhibits both low and high  $b$ -values ( $b \sim 1$  and  $4.2 < b < 5$ ,  
4 respectively) (Kao et al., 2010; Sweet et al., 2014; Bostock et al., 2015). In Chile, the  $b$ -value of NVT  
5 sequences was determined to be 2.4 (Gallego et al., 2013). Regarding  $b$ -value estimations of NVTs at  
6 the Cocos plate, Rabbel et al. (2011) estimated a value of 1 in the region of Costa Rica. Our results  
7 show that the  $b$ -value varies from 1.25 to 2.42 for the NVTs detected in the Mexican subduction regime  
8 studied. We observed that in the down-dip segment, NVT sequences have the highest  $b$ -values (2.22-  
9 2.42), while in the interplate coupling region, the  $b$ -value ranges from 1.25 to 1.41 (Table 2). High  $b$ -  
10 values may indicate a greater degree of fracturing, as they reflect a larger proportion of small-  
11 magnitude events relative to larger ones. In general, the  $b$ -values obtained for the coupling region do  
12 not differ significantly from those reported for tectonic earthquakes. For example, for the Cocos plate,  
13 the  $b$ -value for tectonic seismic events has been observed to lie in the interval of 0.8 – 1.3 (Nishikawa  
14 and Ide, 2014).

15  
16 Temporal variations in seismic network geometry can significantly influence the magnitude of  
17 completeness ( $M_c$ ) for NVT sequences. Sequences 1-3 (Ide, 2012; Idehara et al., 2014) were recorded  
18 using temporary networks such as MARS and MASE, where changes in station coverage over time  
19 affected event detection and  $M_c$  estimates ( $N = 1908, 1411, 6776$ ;  $M_w$  ranges -0.27 to 3.65, -0.40 to  
20 3.21, -0.80 to 2.00). Sequence 4 (Husker et al., 2019) was analyzed using limited station coverage,  
21 constraining the detection of low-magnitude events, although magnitudes were not estimated ( $N =$   
22 23408). In contrast, sequences 5 (Plata-Martínez et al., 2021) and 6 (Chen et al., 2025) used submarine  
23 seismometers, allowing reliable detection of events, despite Chen et al. (2025) not reporting  
24 magnitudes ( $N = 101$  and 637;  $M_w$  ranges 0.10 to 2.70 and not reported, respectively). These examples

1 demonstrate that temporal changes in network configuration, station density, and instrument type may  
2 directly affect  $M_c$  and, consequently, influence  $b$ -value calculations and their interpretation for NVT  
3 catalogs.

4

5 In terms of the non-extensive statistical analysis, our estimates of the  $q$ -value for NVTs in Mexico are  
6 consistent with previous reports from subduction zones, where  $q$ -values range from 1.61 to 1.69  
7 (Scherrer et al., 2015). These results agree with our findings, in which the  $q$ -value varies from 1.64 to  
8 1.65. Our results also show that down-dip interplate sequences have lower  $q$ -values (1.39) (Table 3).  
9 High  $q$ -values in coastal regions may be explained by greater stress heterogeneity, associated with plate  
10 coupling and asperity distribution, compared to down-dip regions, where different conditions, such as  
11 pressure, temperature, and rock structure prevail.

12

13 Regarding the multifractal analysis, our results indicate that both magnitude and interevent time NVT  
14 sequences exhibit multifractal structures similar to those observed in tectonic earthquakes (interevent  
15 time, Michas et al., 2015; magnitude, De Freitas and França, 2024). Tests based on surrogate data show  
16 that only one sequence exhibits intrinsic multifractality, while four sequences display apparent  
17 multifractality and five sequences yield inconclusive results. De Freitas and França (2024) also  
18 reported that seismicity in some subduction zones shows apparent multifractality, whereas others  
19 exhibit intrinsic multifractality, which is consistent with our findings. The estimated Hurst exponent  
20 ( $H$ ) values further illustrate the heterogeneity of the sequences, ranging from 0.65 to 1.06 (Table 4).  
21 Several sequences fall within the range typically associated with persistent behavior ( $0.5 < H < 1.0$ ),  
22 while some sequences, including magnitude sequences 1, 2, and 5, reach or slightly exceed  $H = 1.0$ .  
23 Values above unity should be interpreted with caution, as they may indicate non-stationary or trending

1 behavior, rather than purely long-range dependence. Nonetheless, these high values may reflect strong  
2 temporal correlations in certain sequences.

3

4 High  $H$  values have previously been linked to fault-zone properties (Cisternas et al., 2004). While we  
5 hypothesize that they could reflect limited volumes of perturbed regions containing fluids, this  
6 interpretation remains speculative. The observed  $H$  values are statistically comparable to those reported  
7 for regional seismicity and aftershock sequences: southern Italy (0.5 - 0.92, Telesca et al., 2001),  
8 Taiwan and Greece ( $\sim 0.8$ , Chen et al., 2008; Gkarlaoui et al., 2017), and the San Andreas Fault  
9 ( $\sim 0.87$ , De Freitas et al., 2013), with Izmit aftershocks reaching 0.95 (Cisternas et al., 2004). Although  
10 fundamental differences exist between aftershock relaxation and NVT generation, the similarity in  
11 scaling behavior suggests comparable long-term memory in the underlying processes. The surrogate  
12 analysis indicates that the physical origin of multifractality is not uniform across sequences. Magnitude  
13 sequence 1 and interevent time sequences 2, 3, and 6 show statistically significant deviations from  
14 surrogate data, suggesting contributions from temporal correlations and potential nonlinear interactions,  
15 whereas other sequences are consistent with apparent multifractality arising from broad distributions or  
16 finite-size effects. Overall, these results support the interpretation that the observed multifractal  
17 behavior arises from a combination of mechanisms, whose relative influence varies across sequences  
18 and depends on their temporal organization.

19

20 The interevent time analysis showed that NVT sequences 1 to 4 are well described by a Lognormal  
21 distribution, while sequences 5 and 6 are better fitted by a Gamma distribution (Table 5). Although the  
22 Lognormal distribution provides the best fit for sequences 1 to 4, it can also occur in purely tectonic  
23 settings (Mesimeri et al., 2019), and thus its presence alone does not imply mixed tectonic-volcanic  
24 behavior. Our interpretation of “mixed behavior” is supported by additional indicators, including

1 magnitude ranges,  $q$ -values, and variability in short- and long interevent times. Traversa and Grasso  
2 (2010) showed that a Gamma distribution mainly describes volcanic seismicity, although some  
3 episodes deviate from it, while purely tectonic activity can be captured by Exponential, Gamma, or  
4 Lognormal distributions (Corral, 2006; Passarelli et al., 2015; Post et al., 2021). Our results align with  
5 both global ( $M_w \geq 7$ , Bantidi, 2022) and regional ( $0.1 < M_L < 5.1$ , Mesimeri et al., 2019) studies, where  
6 Lognormal distributions often provide the best description of interevent times. For sequences 5 and 6,  
7 the statistical preference for the Lognormal distribution is less clear, likely due to smaller sample sizes  
8 (Table 1), which increases uncertainty in the fits. Overall, the observed differences between down-dip  
9 and interplate coupling regions are consistent with this interpretation, with the Gamma distribution  
10 better explaining observations in the latter, likely reflecting the lower number of detected events.

11

12 Finally, the scaling relationship between tremor duration and magnitude for all NVT sequences exhibits  
13 substantial scatter. Although positive slope coefficients are consistently observed in  $\log(\tau) = a + bM_w$ ,  
14 the low coefficients of determination ( $R^2 = 0.03-0.34$ ) indicate a weak dependence of duration on  
15 magnitude, in contrast to the more robust scaling observed for regular earthquakes. Part of this  
16 variability may be related to observational limitations, as tremors lack clear phase arrivals and their  
17 parameters (e.g., duration, magnitude, and amplitudes) are more difficult to constrain (Staudenmaier et  
18 al., 2019). However, the persistence of this scatter across all sequences, despite similar tectonic settings  
19 and depths, suggests that it is not primarily controlled by first-order structural differences. Instead, this  
20 weak scaling likely reflects the complex and heterogeneous nature of tremor generation. Consistent  
21 with previous studies (Schwartz and Rokosky, 2007), this behavior suggests that tremor duration and  
22 magnitude may be governed by partially independent processes, highlighting that NVT does not follow  
23 simple earthquake-like scaling relationships. Although the relationship between slow earthquakes and  
24 tectonic tremors is not fully understood, there is evidence that NVTs are modulated by slow

1 dislocations on the plate interface (Villafuerte and Cruz-Atienza, 2017).

2

### 3 **6 Conclusions**

4 We investigated the statistical features of reported NVT sequences along the Mexican subduction zone,  
5 analyzing the Gutenberg-Richter relation, non-extensive statistics, and multifractal behavior of  
6 magnitude and interevent time series. The estimated  $b$ -values range from 1.25 to 2.42, consistent with  
7 previous reports worldwide, with the highest values observed in down-dip regions. In contrast,  $q$ -values  
8 are lower in these regions compared to coastal areas ( $1.39 < q < 1.65$ ), in agreement with the inverse  
9 relationship between  $b$  and  $q$  proposed in previous studies ( $b = 2(2-q)/(1-q)$ ). Although quantitative  
10 differences exist, both approaches consistently indicate that higher  $b$ -values correspond to lower  $q$ -  
11 values. Both magnitude and interevent-time series exhibit multifractal behavior, similar to tectonic  
12 earthquakes. Our results show that the origin of this multifractality is not uniform across sequences, but  
13 rather arises from a combination of mechanisms whose relative importance varies. In several cases, the  
14 observed behavior is consistent with apparent multifractality associated with broad probability  
15 distributions, whereas in others, statistically significant deviations from surrogate data indicate  
16 contributions from long-range correlations and possible nonlinear dynamics. Overall, the results  
17 suggest that no single mechanism dominates and that the multifractal properties reflect the  
18 heterogeneous temporal organization of the sequences.

19

20 Most NVT sequences are well described by a Lognormal model, while a few are better fitted by a  
21 Gamma distribution. Although lognormal fits are common, they can also occur in purely tectonic  
22 settings; therefore, their presence alone does not imply mixed tectonic-volcanic behavior. Evidence  
23 from magnitude ranges, multifractal parameters, and interevent-time variability supports the  
24 interpretation of mixed statistical characteristics. These findings highlight the complex temporal

1 patterns of NVT sequences and differences in clustering across regions. The relationship between  
2 tremor duration and magnitude, however, shows substantial scatter, resulting in weak scaling with low  
3 coefficients of determination. While positive scaling coefficients are consistently observed, their  
4 magnitudes remain poor predictors of tremor duration. Part of this variability may reflect observational  
5 uncertainties, as tremor signals lack clear phase arrivals and their parameters are difficult to constrain.  
6 Nevertheless, the persistence of this behavior across all sequences, despite similar tectonic settings and  
7 depths, suggests that first-order structural differences do not primarily control it. Rather, the weak  
8 correlation likely reflects the complex, heterogeneous nature of tremor generation, in which partially  
9 independent or multiscale processes may govern duration and magnitude.

10

11 *Code availability.* Estimations of  $b$ -value were performed with the Python code `Calc_gr_ks`  
12 (<https://github.com/nadavwetzler/b-value>; Wetzler, 2022). We calculate the interevent-time  
13 distributions with the code `qks_statistics` ([https://github.com/mmesim/qks\\_statistics](https://github.com/mmesim/qks_statistics); Mesimeri, 2021).  
14 The MFDMA method was implemented with the code `GFGU_MFDMA_1D` (Gu and Zhou, 2010).  
15 MATLAB Chaotic Systems Toolbox for implementing shuffle and IAAFT surrogate time series are  
16 available at [https://github.com/nmitrou/Simulations/tree/master/matlab\\_codes](https://github.com/nmitrou/Simulations/tree/master/matlab_codes) (Leontitsis, 2001).  
17 Linear regressions for NVT duration scaling relations were determined with the SciPy library (Virtanen  
18 et al., 2020). Some figures were produced with Generic Mapping Tools (GMT) (Wessel et al., 2019). In  
19 all cases, last access: September 2025.

20

21 *Data availability.* NVT catalogs for sequences 1 to 3 were taken from the World Tremor Database  
22 (<http://www-solid.eps.s.u-tokyo.ac.jp/~idehara/wtd0/Welcome.html>, Ide, 2012; Idehara et al., 2014).  
23 Catalogs for sequences 4, 5, and 6 were obtained from Husker et al. (2019), Plata-Martínez et al.  
24 (2021), and Chen et al. (2025), respectively. In all cases, last access: September 2025.

1

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11

## 12 **References**

13 Aki, K.: Maximum likelihood estimate of  $b$  in the formula  $\log N = a - bM$  and its confidence limits,  
14 Bull. Earthq. Res. Inst., Univ. Tokyo 43, 237-239, 1965.

15

16 Alam, A., Nikolopoulos, D., Cantzos, D., Tahir, M., Iqbal, T., Petraki, E., and Rafique, M.: Regional  
17 multifractal variability of overall seismic activity in Pakistan from 1820 to 2020 via the application of  
18 MDFA on earthquake catalogs, Fractal and Fractional, 7, 857,  
19 <https://doi.org/10.3390/fractalfract7120857>, 2023.

20

21 Bantidi, T.M.: Inter-occurrence time statistics of successive large earthquakes: analyses of the global  
22 CMT dataset, Acta Geophys., 70, 2603–2619, <https://doi.org/10.1007/s11600-022-00908-2>, 2022.

23

24 Bostock, M. G., Thomas, A. M., Savard, G., Chuang, L., and Rubin, A. M.: Magnitudes and moment-

1 duration scaling of low-frequency earthquakes beneath southern Vancouver Island, *J. Geophys. Res.*,  
2 120, 6329-6350, <https://doi.org/10.1002/2015JB012195>, 2015.

3  
4 Brudzinski, M. R., Hinojosa-Prieto, H. R., Schlanser, K. M., Cabral-Cano, E., Arciniega-Ceballos, A.,  
5 Diaz-Molina, O., and DeMets, C.: Nonvolcanic tremor along the Oaxaca segment of the Middle  
6 America subduction zone, *J. Geophys. Res.*, 115, B00A23, <https://doi.org/10.1029/2008JB006061>,  
7 2010.

8  
9 Chen, C.-C., Lee, Y.-T., and Chang, Y.-F.: A relationship between Hurst exponents of slip and waiting  
10 time data of earthquakes, *Physica A*, 387, 4643-4648, <https://doi.org/10.1016/j.physa.2007.08.063>,  
11 2008.

12  
13 Chen, Y., Ito, Y., Plata-Martinez, R., Dominguez, L. A., Ohyanagi, S., Garcia, E. S., Flores, K., Cruz-  
14 Atienza, V. M., Shinohara, M., and Yamashita, Y.: New insight into slow earthquake activities from  
15 continuous ocean bottom seismometers at the Guerrero seismic gap, Mexico, *Geophys. J. Int.*, 241,  
16 511-525, <https://doi.org/10.1093/gji/ggaf057>, 2025.

17  
18 Cisternas, A., Polat, O., and Rivera, L.: The Marmara Sea region: Seismic behaviour in time and the  
19 likelihood of another large earthquake near Istanbul (Turkey), *J. Seismol.*, 8, 427-437,  
20 <https://doi.org/10.1023/B:JOSE.0000038451.04626.18>, 2004.

21  
22 Corral, A.: Dependence of earthquake recurrence times and independence of magnitudes on seismicity  
23 history, *Tectonophysics*, 424, 177-193, <https://doi.org/10.1016/j.tecto.2006.03.035>, 2006.

24

1 Cruz-Atienza, V. M., Husker, A., Legrand, D., Caballero, E., and Kostoglodov, V.: Nonvolcanic tremor  
2 locations and mechanisms in Guerrero, Mexico, from energy-based and particle motion polarization  
3 analysis, *J. Geophys. Res.*, 120, 275-289, <https://doi.org/10.1002/2014JB011389>, 2015.  
4

5 Davidsen, J., and Kwiatek, G.: Earthquake interevent time distribution for induced micro-, nano-, and  
6 picoseismicity, *Phys. Rev. Lett.*, 110, 1-5, <https://doi.org/10.1103/PhysRevLett.110.068501>, 2013.  
7

8 DeMets, C., Gordon, R., Argus, D., and Stein, S.: Effect of recent revisions to the geomagnetic reversal  
9 time scale on estimates of current plate motions, *Geophys. Res. Lett.*, 21, 2191-2194,  
10 <http://dx.doi.org/10.1029/94GL02118>, 1994.  
11

12 De Freitas, D. B., and De Medeiros, J. R.: Nonextensivity in the solar magnetic activity during the  
13 increasing phase of the solar cycle 23, *EPL*, 88, 19001, <https://doi.org/10.1209/0295-5075/88/19001>,  
14 2009.  
15

16 De Freitas, D. B., França, G. S., Scherrer, T. M., Vilar, C. S., Silva, R.: Nonextensive triplet in a  
17 geological faults system, *EPL*, 102, 39001, <https://doi.org/10.1209/0295-5075/102/39001>, 2013.  
18

19 De Freitas, D. B., and França, G. S.: Analyzing the intrinsic multifractal nature of seismic sequences  
20 distributed along the Pacific Ring of Fire, *EPL*, 146, 60002, <https://doi.org/10.1209/0295-5075/ad5101>,  
21 2024.  
22

23 Gallego, A., Russo, R. M., Comte, D., Mocanu, V., Murdie, R. E., VanDecat, J. C.: Tidal modulation of  
24 continuous nonvolcanic seismic tremor in the Chile triple junction region, *Geochem. Geophys. Geosy.*,

1 14, 851-863, <https://doi.org/10.1002/ggge.20091>, 2013.

2

3 Gkarlaouni, C., Lasocki, S., Papadimitriou, E., and George, T.: Hurst analysis of seismicity in Corinth  
4 rift and Mygdonia graben (Greece), *Chaos Soliton. Fract.*, 96, 30-42,  
5 <https://doi.org/10.1016/j.chaos.2017.01.001>, 2017.

6

7 Gomberg, J., Wech, A., Creager, K., Obara, K., and Agnew, D.: Reconsidering earthquake scaling.  
8 *Geophys. Res. Lett.*, 43, 6243-6251, <https://doi.org/10.1002/2016GL069967>, 2016a.

9

10 Gomberg, J., Agnew, D. C., and Schwartz, S. Y.: Alternative source models of very low frequency  
11 events, *J. Geophys. Res.*, 121, 6722-6740, <https://doi.org/10.1002/2016JB013001>, 2016b.

12

13 Gu, G-F., and Zhou, W-X.: Detrend moving average algorithm for multifractals, *Phys. Rev. E*, 82,  
14 011136, <https://doi.org/10.1103/PhysRevE.82.011136>, 2010.

15

16 Gutenberg, B., and Richter, C. F.: Frequency of earthquakes in California, *Bull. Seism. Soc. Am.*, 34,  
17 185-188, <https://doi.org/10.1785/BSSA0340040185>, 1944.

18

19 Hampson, K. M., Mallen, E. A. H.: Multifractal nature of ocular aberration dynamics of the human eye,  
20 *Biomedical Optics Express*, 2, 464, <https://doi.org/10.1364/BOE.2.000464>, 2011.

21

22 Hayes, G. P., Wald, D. J., and Johnson, R. L.: Slab1.0: a three-dimensional model of global subduction  
23 zone geometries, *J. Geophys. Res.*, 117, B01302, <https://doi.org/10.1029/2011JB008524>, 2012.

24

1 Henderson, J., Main, I. G., Pearce, R. G., and Takeya, M.: Seismicity in north-eastern Brazil—Fractal  
2 clustering and the evolution of the  $b$ -value, *Geophys. J. Int.*, 116, 217-226,  
3 <https://doi.org/10.1111/j.1365-246X.1994.tb02138.x>, 1994.  
4  
5 Husker, A., Frank, W. B., Gonzalez, G., Avila, L., Kostoglodov, V., and Kazachkina, E.: Characteristic  
6 tectonic tremor activity observed over multiple slow slip cycles in the Mexican subduction zone, *J.*  
7 *Geophys. Res.*, 124, 599-608, <https://doi.org/10.1029/2018JB016517>, 2019.  
8  
9 Ide, S.: Variety and spatial heterogeneity of tectonic tremor worldwide, *J. Geophys. Res.*, 117, B03302,  
10 <https://doi.org/10.1029/2011JB008840>, 2012.  
11  
12 Idehara, K., Yabe, S., and Ide, S.: Regional and global variations in the temporal clustering of tectonic  
13 tremor activity, *Earth Planets. Sp.*, 66, 66, <https://doi.org/10.1186/1880-5981-66-66>, 2014.  
14  
15 Ihlen, E. A. F.: Introduction to multifractal detrended fluctuation analysis in Matlab, *Front. Physiol.*, 3,  
16 141, <https://doi.org/10.3389/fphys.2012.00141>, 2012.  
17  
18 Jiang Z.-Q., Xie, W.-J., Zhou, W.-X., and Sornette, D.: Multifractal analysis of financial markets, *Rep.*  
19 *Prog. Phys.*, 82, 125901, <https://doi.org/10.1088/1361-6633/ab42fb>, 2019.  
20  
21 Kantelhardt, J. W., Zschiegner, S. A., Koscielny-Bunde, E., Havlin, S., Bunde, A., and Stanley, H. E.:  
22 Multifractal detrended fluctuation analysis of nonstationary time series, *Physica A*, 316, 87-114,  
23 [https://doi.org/10.1016/S0378-4371\(02\)01383-3](https://doi.org/10.1016/S0378-4371(02)01383-3), 2002.  
24

1 Kantelhardt, J.W.: Fractal and multifractal time series. In: Meyers, R. (eds) Encyclopedia of  
2 Complexity and Systems Science. Springer, New York, NY. [https://doi.org/10.1007/978-0-387-30440-](https://doi.org/10.1007/978-0-387-30440-3_221)  
3 [3\\_221](https://doi.org/10.1007/978-0-387-30440-3_221), 2009.

4  
5 Kao, H., Wang, K., Dragert, H., Kao, J. Y., and Rogers, G.: Estimating seismic moment magnitude  
6 ( $M_w$ ) of tremor bursts in northern Cascadia: Implications for the “seismic efficiency” of episodic  
7 tremor and slip, *Geophys. Res. Lett.*, 37, L19306, <https://doi.org/10.1029/2010GL044927>, 2010.

8  
9 Lay, T., and Wallace, T.: *Modern global seismology*. ISBN: 012732870X, pp 521., 1995.

10  
11 Leontitsis, A.: Chaotic Systems Toolbox. Code available at  
12 [https://github.com/nmitrou/Simulations/tree/master/matlab\\_codes](https://github.com/nmitrou/Simulations/tree/master/matlab_codes), 2001.

13  
14 Mesimeri, M., Karakostas, V., Papadimitriou, E., and Tsaklidis, G.: Characteristics of earthquake  
15 clusters: Application to western Corinth Gulf (Greece), *Tectonophysics*, 767, 228160,  
16 <https://doi.org/10.1016/j.tecto.2019.228160>, 2019.

17  
18 Mesimeri, M.: Qks\_statistics: Utils for earthquake statistics. Code available at  
19 [https://github.com/mmesim/qks\\_statistics](https://github.com/mmesim/qks_statistics), 2021.

20  
21 Michas, G., Sammonds, P., and Vallianatos, F.: Dynamic multifractality in earthquakes time series:  
22 insights from Corinth Rift, Greece, *Pure Appl. Geophys.*, 172, 1909-1921,  
23 <https://doi.org/10.1007/s00024-014-0875-y>, 2015.

24

1 Miyazawa, M., and Mori, J.: Detection of triggered deep low-frequency events from the 2003 Tokachi-  
2 oki earthquake, *Geophys. Res. Lett.*, 32, L10307, <https://doi.org/10.1029/2005GL022539>, 2005.

3

4 Mogi, K.: Some discussions on aftershocks, foreshocks and earthquake swarms: The fracture of a semi-  
5 infinite body caused by an inner stress origin and its relation to the earthquake phenomena, *Bull.*  
6 *Earthq. Res. Inst.*, 41, 615-658, 1963.

7

8 Monterrubio-Velasco, M., Lana, X., Martínez, M. D., Zúñiga, F. R., and Puente, J. D. L.: Evolution of  
9 the multifractal parameters along different steps of a seismic activity. The example of Canterbury  
10 2000–2018 (New Zealand), *AIP Advances*, 10, <https://doi.org/10.1063/5.0010103>, 2020.

11

12 Nadeau, R. M., and Dolenc, D.: Nonvolcanic tremors deep beneath the San Andreas Fault, *Science*,  
13 307, 389, <https://doi.org/10.1126/science.1107142>, 2005.

14

15 Nishikawa, T., and Ide, S.: Earthquake size distribution in subduction zones linked to slab buoyancy,  
16 *Nature Geosci.*, 7, 904-908, <https://doi.org/10.1038/ngeo2279>, 2014.

17

18 Obara, K.: Nonvolcanic deep tremor associated with subduction in southwest Japan, *Science*, 296,  
19 1679-1681, <https://doi.org/10.1126/science.107037>, 2002.

20

21 Pardo, M., and Suárez, G.: Shape of the subducted Rivera and Cocos plates in southern Mexico:  
22 Seismic and tectonic implications, *J. Geophys. Res.*, 100, 12357-12373,  
23 <https://doi.org/10.1029/95JB00919>, 1995.

24

1 Passarelli, L., Hainzl, S., Cesca S., Maccaferri, F., Mucciarelli, M., Roessler, D., Corbi, F., and Dahm,  
2 T.: Aseismic transient driving the swarm-like seismic sequence in the Pollino range, Southern Italy,  
3 *Geophys. J. Int.*, 201, 1553-1567, <https://doi.org/10.1093/gji/ggv111>, 2015.

4

5 Payero, J. S., Kostoglodov, V., Shapiro, N., Mikumo, T., Iglesias, A., Pérez-Campos, X., and Clayton,  
6 R. W.: Nonvolcanic tremor observed in the Mexican subduction zone, *Geophys. Res. Lett.*, 35, L07305,  
7 <https://doi.org/10.1029/2007GL032877>, 2008.

8

9 Peacock, S. M.: Thermal and metamorphic environment of subduction zone episodic tremor and slip, *J.*  
10 *Geophys. Res.*, 114, B00A07, <https://doi.org/10.1029/2008JB005978>, 2009.

11

12 Pérez-Campos, X., Kim, Y. H., Husker, A., Davis, P. M., Clayton, R. W., Iglesias, A., Pacheco, J. F.,  
13 Singh, S. K., Manea, V. C., and Gurnis, M.: Horizontal subduction and truncation of the Cocos Plate  
14 beneath central Mexico, *Geophys. Res. Lett.*, 35, L18303, <https://doi.org/10.1029/2008GL035127>,  
15 2008.

16

17 Plata-Martinez, R., Ide, S., Shinohara, M., Garcia, E. S., Mizuno, N., Dominguez, L. A., Taira, T.,  
18 Yamashita, Y., Toh, A., Yamada, T., Real, J., Husker, A., Cruz-Atienza, V. M., and Ito, Y.: Shallow slow  
19 earthquakes to decipher future catastrophic earthquakes in the Guerrero seismic gap, *Nat. Commun.*,  
20 12, 3976, <https://doi.org/10.1038/s41467-021-24210-9>, 2021.

21

22 Post, R. A. J., Michels, M. A. J., Ampuero, J.-P., Candela, T., Fokker, P. A., Van Wees, J.-D., Van der  
23 Hofstad, R. W., and Van den Heuvel, E. R.: Interevent time distribution and aftershock frequency in  
24 non-stationary induced seismicity, *Sci. Rep.* 11, 3540, <https://doi.org/10.1038/s41598-021-82803-2>,

1 2021.

2

3 Rabbel, W., Thorwart, M. M., and Taylor, W.: Non-volcanic tremor in Costa Rica: *b*-values, moment  
4 release and tidal modulation, AGU Fall Meeting 2011, Online, 5–9 December 2011, S23B-2245,  
5 <https://ui.adsabs.harvard.edu/abs/2011AGUFM.S23B2245R/abstract>, 2011.

6

7 Rogers, G., and Dragert, H.: Episodic tremor and slip on the Cascadia subduction zone: the chatter of  
8 silent slip, *Science*, 300, 1942-19443, <https://doi.org/10.1126/science.108478>, 2003.

9

10 Rubinstein, J. L., Vidale, J. E., Gomberg, J., Bodin, P., Creager, K. C., and Malone, S. D.: Non-volcanic  
11 tremor driven by large transient shear stresses, *Nature*, 448, 579-582,  
12 <https://doi.org/10.1038/nature06017>, 2007.

13

14 Saichev, A., Sornette, D.: Generic multifractality in exponentials of long memory processes, *Phys. Rev.*  
15 *E*, 74, 011111, <http://dx.doi.org/10.1103/PhysRevE.74.011111>, 2006.

16

17 Sarlis, N. V., Skordas, E. S., and Varotsos, P. A.: Nonextensivity and natural time: the case of  
18 seismicity, *Phys Rev E*, 82, 021110, <http://dx.doi.org/10.1103/PhysRevE.82.021110>, 2010.

19

20 Scherrer, T. M., França, G. S., Silva, R., de Freitas, D. B., and Vilar, C. S.: Nonextensivity at the  
21 Circum-Pacific subduction zones—Preliminary studies, *Physica A*, 426, 63-71,  
22 <https://doi.org/10.1016/j.physa.2014.12.038>, 2015.

23

24 Scholz, C. H.: On the stress dependence of the earthquake *b*-value, *Geophys. Res. Lett.*, 42, 1399-1402,

1 <https://doi.org/10.1002/2014GL062863>, 2015.

2

3 Schorlemmer, D., Wiemer, S., and Wyss, M.: Variations in earthquake-size distribution across different  
4 stress regimes, *Nature*, 437, 539-542, <https://doi.org/10.1038/nature04094>, 2005.

5

6 Schreiber, T., and Schmitz, A.: Improved surrogate data for nonlinearity tests, *Phys. Rev. Lett.*, 77, 635-  
7 638, <https://doi.org/10.1103/PhysRevLett.77.635>, 1996.

8

9 Schreiber, T., and Schmitz, A.: Surrogate time series, *Physica D: Nonlinear Phenomena*, 142, 346-382,  
10 [https://doi.org/10.1016/S0167-2789\(00\)00043-9](https://doi.org/10.1016/S0167-2789(00)00043-9), 2000.

11

12 Schwartz, S. Y., Rokosky, J. M.: Slow slip events and seismic tremor at circum-Pacific subduction  
13 zones, *Rev. Geophys.*, 45, RG3004, <https://doi.org/10.1029/2006RG000208>, 2007.

14

15 Shelly, D. R., Beroza, G. C., Ide, S., and Nakamura, S.: Low-frequency earthquakes in Shikoku, Japan,  
16 and their relationship to episodic tremor and slip, *Nature*, 442, 188-191,  
17 <https://doi.org/10.1038/nature04931>, 2006.

18

19 Shelly, D. R., Beroza, G. C., and Ide, S.: Non-volcanic tremor and low-frequency earthquake swarms,  
20 *Nature*, 446, 305-307, <https://doi.org/10.1038/nature05666>, 2007.

21

22 Shelly, D. R.: Migrating tremor illuminates deformation beneath the seismogenic San Andreas fault,  
23 *Nature*, 463, 648-652, <https://doi.org/10.1038/nature08755>, 2010.

24

1 Silva, R., Franca, G. S., Vilar, C. S., and Alcaniz, J. S.: Nonextensive models for earthquakes, Phys.  
2 Rev. E, 7, 026102, <http://dx.doi.org/10.1103/PhysRevE.73.026102>, 2006.

3

4 Singh, S. K., and Mortera, F.: Source time functions of large Mexican subduction earthquakes,  
5 morphology of the Benioff Zone, age of the plate, and their tectonic implications, J. Geophys. Res., 96,  
6 21487-21502, <https://doi.org/10.1029/91JB02047>, 1991.

7

8 Sotolongo-Costa, O., and Posadas, A.: Fragment-asperity interaction model for earthquakes, Phys. Rev.  
9 Lett., 92, 048501, <http://dx.doi.org/10.1103/PhysRevLett.92.048501>, 2004.

10

11 Staudenmaier, N., Tormann, T., Edwards, B., Mignan, A., and Wiemer, S.: The frequency-size scaling  
12 of non-volcanic tremors beneath the San Andreas Fault at Parkfield: Possible implications for seismic  
13 energy release, Earth Planet. Sci. Lett., 516, 77-107, <https://doi.org/10.1016/j.epsl.2019.04.006>, 2019.

14

15 Sweet, J. R., Creager, K. C., and Houston, H.: A family of repeating low-frequency earthquakes at the  
16 downdip edge of tremor and slip, Geochem. Geophys. Geosyst., 15, 3713-3721,  
17 <https://doi.org/10.1002/2014GC005449>, 2014.

18

19 Tang, C.-C., Peng, Z., Chao, K., Chen, C.-H., and Lin, C.-H.: Detecting low-frequency earthquakes  
20 within non-volcanic tremor in southern Taiwan triggered by the 2005  $M_w$  8.6 Nias earthquake,  
21 Geophys. Res. Lett., 37, L16307, <https://doi.org/10.1029/2010GL043918>, 2010.

22

23 Telesca, L., Cuomo, V., and Lapenna, V.: A new approach to investigate the correlation between  
24 geoelectrical time fluctuations and earthquakes in a seismic area of southern Italy, Geophys. Res. Lett.,

1 28, 4375-4378, <https://doi.org/10.1029/2001GL013467>, 2001.

2

3 Telesca, L., and Lapenna, V.: Measuring multifractality in seismic sequences, *Tectonophysics*, 423,  
4 115-123, <https://doi.org/10.1016/j.tecto.2006.03.023>, 2006.

5

6 Theiler, J., Eubank, S., Longtin, A., Galdrikian, B., and Farmer, J. D.: Testing for nonlinearity in time  
7 series: the method of surrogate data, *Physica D*, 58, 77-94, <https://doi.org/10.1016/0167->  
8 2789(92)90102-S, 1992.

9

10 Traversa, P., and Grasso, J.-R.: How is volcano seismicity different from tectonic seismicity?, *B.*  
11 *Seismol. Soc. Am.*, 100, 1755-1769, <https://doi.org/10.1785/0120090214>, 2010.

12

13 Tsallis, C.: Introduction to nonextensive statistical mechanics. *Approaching a Complex World*,  
14 Springer, New York, 382pp., 2009.

15

16 Villafuerte, C., and Cruz-Atienza, V. M.: Insights into the causal relationship between slow slip and  
17 tectonic tremor in Guerrero, Mexico, *J. Geophys. Res.*, 122, 6642-6656,  
18 <https://doi.org/10.1002/2017JB014037>, 2017.

19

20 Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E.,  
21 Peterson, P., Weckesser, W., Bright, J., Van der Walt, S. J., Brett, M., Wilson, J., Millman, K. J.,  
22 Mayorov, N., Nelson, A. R. J., Jones, E., Kern, R., Larson, E., Carey, C. J., Polat, I., Feng, Y., Moore,  
23 E. W., and VanderPlas, J.: SciPy 1.0: Fundamental algorithms for scientific computing in Python. *Nat.*  
24 *Methods*, 17, 261-272, <https://doi.org/10.1038/s41592-019-0686-2>, 2020.

1

2 Wada, I., Wang, K., He, J., and Hyndman, R. D.: Weakening of the subduction interface and its effects  
3 on surface heat flow, slab dehydration, and mantle wedge serpentinization, *J. Geophys. Res.*, 113,  
4 B04402, <https://doi.org/10.1029/2007JB005190>, 2008.

5

6 Wang, L., Gao, X.-L., and Zhou, W.-X.: Testing for intrinsic multifractality in the global grain spot  
7 market indices: a multifractal detrended fluctuation analysis, *Fractals*, 31, 2350090,  
8 <https://doi.org/10.1142/S0218348X23500901>, 2023.

9

10 Warren, N. W., and Latham, G. V.: An experimental study of thermally induced microfracturing and its  
11 relation to volcanic seismicity, *J. Geophys. Res.*, 75, 4455-4464,  
12 <https://doi.org/10.1029/JB075i023p04455>, 1970.

13

14 Wessel , P. , Luis, J. F., Uieda, L. A., Scharroo, R., Wobbe, F., Smith, W. H., Tian, D.: The generic  
15 mapping tools version 6, *Geochem. Geophys. Geosyst.*, 20, 5556-5564,  
16 <https://doi.org/10.1029/2019GC008515>, 2019.

17

18 Wetzler, N.: Calc\_gr\_ks.py: A program to calculate the *b*-value Gutenberg-Richter magnitude  
19 distribution using the Kolmogorov–Smirnov test. Code available at [https://github.com/nadavwetzler/b-](https://github.com/nadavwetzler/b-value)  
20 *value*, 2022.

21

22 Woessner, J., and Wiemer, S.: Assessing the quality of earthquake catalogues: estimating the magnitude  
23 of completeness and Its uncertainty, *Bull. Seism. Soc. Am.*, 95, 684-698,  
24 <https://doi.org/10.1785/0120040007>, 2005.

1

2 Yoshioka, S., Toda, M., and Nakajima, J.: Regionality of deep low-frequency earthquakes associated  
3 with subduction of the Philippine Sea plate along the Nankai Trough, southwest Japan, *Earth Planet.*  
4 *Sci. Lett.*, 272, 189-198, <https://doi.org/10.1016/j.epsl.2008.04.039>, 2008.

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1 **Table 1.** Studied non-volcanic tremor sequences.  $N$  is the number of events;  $M_w$  is the moment  
 2 magnitude;  $T_1$  and  $T_2$  are the start and end dates of the located NVTs.

Sequence	N	Instrumentation	$T_1$ yyyy/mm/dd	$T_2$ yyyy/mm/dd	$M_w$	Reference
1	1908	temporary land	2005/01/14	2007/05/28	-0.27 – 3.65	Ide (2012), Idehara et al. (2014)
2	1411	temporary land	2006/01/26	2007/06/06	-0.40 – 3.21	Ide (2012), Idehara et al. (2014)
3	6776	temporary land	2009/11/26	2013/08/11	-0.80 – 2.00	Ide (2012), Idehara et al. (2014)
4	23408	single station	2009/03/04	2022/05/29		Husker et al. (2019)
5	101	ocean bottom	2017/11/22	2018/11/12	0.10 – 2.70	Plata-Martínez et al. (2021)
6	637	ocean bottom	2017/11/21	2019/09/10		Chen et al. (2025)

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5 **Table 2.** Results for the Gutenberg-Richter relationship. Uncertainties were quantified based on a  
 6 bootstrap approach.

Sequence	$b$ -value	$a$ -value	$M_c$
1	$2.42 \pm 0.43$	$6.50 \pm 0.85$	$1.80 \pm 0.13$
2	$1.41 \pm 0.10$	$4.17 \pm 0.12$	$1.10 \pm 0.08$
3	$2.22 \pm 0.02$	$5.31 \pm 0.02$	$1.10 \pm 0.02$
5	$1.25 \pm 0.02$	$3.50 \pm 0.02$	$1.60 \pm 0.02$

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9 **Table 3.** Results for the fragment asperity model. Uncertainties were quantified based on a bootstrap  
 10 approach.

Sequence	$q$ -value	$a_s$ -value
1	$1.39 \pm 0.02$	$4.34 \times 10^4 \pm 8.95 \times 10^3$
2	$1.64 \pm 0.02$	$60.24 \pm 38.2$
3	$1.39 \pm 0.04$	$24.36 \pm 4.29$
5	$1.65 \pm 0.01$	$4.98 \times 10^3 \pm 1.56 \times 10^3$

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13 **Table 4.** Testing multifractality of multifractal parameters.  $M_w$  is the moment magnitude;  $\Delta t$  is the  
 14 interevent times;  $A$  is the degree of asymmetry;  $\Delta\alpha$  is the degree of multifractality;  $\Delta f$  is the singularity  
 15 parameter; and  $H$  is the Hurst index. The symbol  $\langle \rangle$  denotes the mean and  $\sigma$  indicates the standard  
 16 deviation. The  $p$ -values represent the proportion of IAAFT surrogates measured for each indicator that  
 17 exceeds the index's value for the original time series.

Parameter	Sequence	$A$	$\langle A \rangle$	$\sigma_A$	$p$ -value	$\Delta\alpha$	$\langle \Delta\alpha \rangle$	$\sigma_{\Delta\alpha}$	$p$ -value	$\Delta f$	$\langle \Delta f \rangle$	$\sigma_{\Delta f}$	$p$ -value	$H$	$\langle H \rangle$	$\sigma_H$	$p$ -value
$M_w$	1	2.96	1.16	0.14	0.00	0.04	0.03	0.002	0.00	-0.060	-0.006	0.005	0.00	1.03	1.03	0.002	0.47
	2	2.83	2.31	1.06	0.25	0.26	0.23	0.070	0.25	-0.370	-0.254	0.203	0.77	1.02	1.02	0.006	0.58
	3	4.67	3.91	0.43	0.05	0.80	0.69	0.061	0.05	-0.980	-0.822	0.118	0.91	0.98	0.99	0.005	0.94
	5	1.04	1.11	0.29	0.56	0.04	0.06	0.014	0.83	-0.002	-0.007	0.022	0.43	1.06	1.06	0.012	0.39
$\Delta t$	1	1.82	1.73	0.36	0.42	1.71	1.70	0.204	0.50	-0.780	-0.452	0.311	0.85	0.82	0.86	0.016	0.99
	2	3.16	2.48	0.66	0.14	1.73	1.32	0.194	0.03	-0.810	-0.724	0.289	0.62	0.92	0.93	0.015	0.80
	3	0.65	0.62	0.13	0.43	1.60	1.23	0.128	0.00	0.413	0.312	0.203	0.34	0.65	0.83	0.025	0.00
	4	0.70	0.88	0.09	0.96	0.80	0.89	0.050	0.98	0.125	0.129	0.132	0.49	0.86	0.90	0.004	0.00
	5	1.02	1.32	0.79	0.58	0.72	0.84	0.256	0.65	0.031	-0.122	0.490	0.41	0.96	0.97	0.060	0.61
	6	3.90	1.49	0.58	0.00	0.90	0.50	0.090	0.00	-1.044	-0.210	0.224	0.99	0.96	0.99	0.021	0.86

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3 **Table 5.** Estimated parameters for the PDF of interevent times. AIC and BIC are the Akaike and  
 4 Bayesian information criteria;  $D$  is the test statistic.

Sequence	Distribution	Parameters	-logL	K-S test		AIC	BIC
				$p$ -value	$D$		
1	Lognormal	$\mu = -3.65$ $\sigma = 2.27$	-2696	0.70	0.10	-5389	-5385
	Weibull	$\alpha = 0.09$ $b = 0.40$	-2399	0.31	0.14	-4795	-4791
	Gamma	$\alpha = 0.25$ $b = 1.78$	-2020	0.02	0.23	-4036	-4033
2	Exponential	$\mu = 0.44$	359	$2.50 \times 10^{-13}$	0.58	719	721
	Lognormal	$\mu = -3.26$ $\sigma = 2.30$	-1424	0.83	0.09	-2845	-2841
	Weibull	$\alpha = 0.12$ $b = 0.44$	-1308	0.39	0.14	-2611	-2608
3	Gamma	$\alpha = 0.31$ $b = 1.11$	-1191	0.08	0.20	-2378	-2375
	Exponential	$\mu = 0.35$	84	$3.81 \times 10^{-9}$	0.48	-166	-164
	Lognormal	$\mu = -4.34$ $\sigma = 1.88$	-15527	0.41	0.13	-31051	-31047
4	Weibull	$\alpha = 0.04$ $b = 0.44$	-14009	0.09	0.18	-28014	-28011
	Gamma	$\alpha = 0.26$ $b = 0.76$	-12035	0.0009	0.28	-24066	-24062
	Exponential	$\mu = 0.20$	-4202	$2.58 \times 10^{-16}$	0.61	-8402	-8400
5	Lognormal	$\mu = -3.30$ $\sigma = 1.64$	-32533	0.62	0.12	-65063	-65059
	Weibull	$\alpha = 0.09$ $b = 0.54$	-28883	0.18	0.17	-57762	-57759
	Gamma	$\alpha = 0.38$ $b = 0.53$	-24665	0.0064	0.27	-49326	-49323
6	Exponential	$\mu = 0.20$	-13681	$2.09 \times 10^{-8}$	0.48	-27359	-27358
	Lognormal	$\mu = -0.39$ $\sigma = 2.86$	208	0.07	0.22	419	423
	Weibull	$\alpha = 2.25$ $b = 0.53$	188	0.47	0.14	382	384
7	Gamma	$\alpha = 0.39$ $b = 9.30$	185	0.68	0.12	374	377
	Exponential	$\mu = 3.65$	229	0.05	0.23	461	462
	Lognormal	$\mu = -2.35$ $\sigma = 3.74$	246	0.07	0.21	495	499
8	Weibull	$\alpha = 0.49$ $b = 0.40$	139	0.26	0.16	283	286
	Gamma	$\alpha = 0.29$ $b = 3.54$	76	0.42	0.14	156	159
	Exponential	$\mu = 1.03$	655	0.01	0.25	1312	1314

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**Table 6.** Duration scaling relationships ( $\log(\tau) = a + b M_w$ ).  $R^2$  is the determination coefficient;  $b$  is the slope and  $a$  is the intercept.

Sequence	$a$	$b$	$R^2$
1	0.696	0.593	0.341
2	1.278	0.104	0.031
3	1.393	0.323	0.161
5	1.024	0.182	0.208

1 **Figure 1.** Tectonic framework of the Mexican subduction zone. TMVB is the Trans-Mexican Volcanic  
2 Belt. CO, NA, PA, and RI are the Cocos, North American, Pacific, and Rivera plates, respectively. GG  
3 is the Guerrero seismic gap. Black arrows indicate the convergence rate among tectonic plates. Dashed  
4 lines represent contour lines of the subducted plate, spaced every 20 km, from 20 to 100 km (Hayes,  
5 2012).

6  
7 **Figure 2.** Hypocenter locations of all the studied non-volcanic tremor sequences along the Mexican  
8 subduction zone. (a) sequence 1, (b) sequence 2, (c) sequence 3, (d) sequence 4, (e) sequence 5, and (f)  
9 sequence 6.

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11 **Figure 3.** Estimates of  $b$ -value and  $M_c$  for the studied NVT sequences. Blue squares show the  
12 cumulative number of events versus magnitude. Red triangles exhibit the number of events. The solid  
13 black lines indicate the Gutenberg-Richter frequency magnitude distributions. (a) sequence 1, (b)  
14 sequence 2, (c) sequence 3, and (d) sequence 5.

15  
16 **Figure 4.** Normalized cumulative number of earthquake with magnitude  $m > M_{th}$  and fitting obtained  
17 with the fragment asperity model for the seismicity monitored in each NVT sequence. (a) sequence 1,  
18 (b) sequence 2, (c) sequence 3, and (d) sequence 5.

19  
20 **Figure 5.** Multifractal analysis of magnitude for sequences 1 (a) and 2 (b) (fluctuation function,  $F(q)$ ;  
21 Hurst exponent,  $h(q)$ ; multifractal scaling exponent  $\tau(q)$ ; and multifractal spectrum  $f(\alpha)$ ). In all cases,  
22 the original, shuffled, and IAAFT surrogates data are shown in red, green, and blue color, respectively.

23  
24 **Figure 6.** Multifractal analysis of magnitude for sequences 3 (a) and 5 (b) (fluctuation function,  $F(q)$ ;

1 Hurst exponent,  $h(q)$ ; multifractal scaling exponent  $\tau(q)$ ; and multifractal spectrum  $f(\alpha)$ ). In all cases,  
2 the original, shuffled, and IAAFT surrogates data are shown in red, green, and blue color, respectively.

3

4 **Figure 7.** Multifractal analysis of interevent time for sequences 1 **(a)** and 2 **(b)** (fluctuation function,  
5  $F(q)$ ; Hurst exponent,  $h(q)$ ; multifractal scaling exponent  $\tau(q)$ ; and multifractal spectrum  $f(\alpha)$ ). In all  
6 cases, the original, shuffled, and IAAFT surrogates data are shown in red, green, and blue color,  
7 respectively.

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9 **Figure 8.** Multifractal analysis of interevent time for sequences 3 **(a)** and 4 **(b)** (fluctuation function,  
10  $F(q)$ ; Hurst exponent,  $h(q)$ ; multifractal scaling exponent  $\tau(q)$ ; and multifractal spectrum  $f(\alpha)$ ). In all  
11 cases, the original, shuffled, and IAAFT surrogates data are shown in red, green, and blue color,  
12 respectively.

13

14 **Figure 9.** Multifractal analysis of interevent time for sequences 5 **(a)** and 6 **(b)** (fluctuation function,  
15  $F(q)$ ; Hurst exponent,  $h(q)$ ; multifractal scaling exponent  $\tau(q)$ ; and multifractal spectrum  $f(\alpha)$ ). In all  
16 cases, the original, shuffled, and IAAFT surrogates data are shown in red, green, and blue color,  
17 respectively.

18

19 **Figure 10.** Probability density functions of the interevent times for the NVT sequences and fitted  
20 curves of different statistical distributions (exponential, Gamma, Lognormal, and Weibull). **(a)**  
21 sequence 1, **(b)** sequence 2, **(c)** sequence 3, **(d)** sequence 4, **(e)** sequence 5, and **(f)** sequence 6.

22

23 **Figure 11.** NVT duration scaling relationships (blue lines). In all figures, color indicates the density of  
24 NVT observations. **(a)** sequence 1, **(b)** sequence 2, **(c)** sequence 3, and **(d)** sequence 5.