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A study on the correlations between seismotectonic *b*-value and *Dc*-value, and seismic quiescence *Z*-value in the Western Anatolian region of Turkey

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Abstract

The Western Anatolian region is one of the most seismically active sectors of Turkey where small-magnitude events with considerable clustering occur frequently. The spatial and temporal behaviors of seismic activity as quantified by the fractal dimension *Dc*-value, seismotectonic *b*-value and seismic quiescence *Z*-value are investigated for the Western Anatolian region. For this purpose, a statistical relationship is developed between b and Dc-values, and regional and temporal changes of these parameters are analyzed in order to reveal the potential of future earthquakes in the study region. By using standard deviate *Z*-value, current seismicity rate changes are estimated in the beginning of 2014.

The Western Anatolian region is divided into 18 different seismogenic subregions. Orthogonal regression fit is preferred in order to estimate more up-to-date and reliable statistical correlation between two seismotectonic parameters. The relationship of $Dc=2.74-0.29*b$ is computed with a significant negative correlation (r = -0.73) between b and *Dc*-values for the Western Anatolian earthquake distributions. There are clear fluctuations in the temporal changes of these two parameters and the same results are relatively obtained in previous studies in literature. Lower *b*-values smaller than 1.0 and also higher *Dc*-value are observed in the Burdur fault zone and Kütahya graben. In addition, the regions in which the lower b-values and the higher *Z*-values are estimated cover the Burdur fault zone, Aliağa-Dumlupınar faults and Bakırçay grabens. Consequently, the relationships between seismic *b*-value, fractal dimension *Dc*-value and seismic quiescence *Z*-value may provide important evidences to put forth the next earthquake potential in Western Anatolia. In addition, monitoring of microseismic activity and behaviors of some other geophysical parameters should be analyzed in space and time and evaluated carefully.

1. Introduction

A number of statistical models have been proposed to describe the physical behaviors of earthquakes by using scaling laws in seismology (e.g., Mandelbrot, 1982; Hirata, 1989; Öncel and Wilson, 2007; Öztürk, 2011; 2012; Roy et al., 2011). In order to evaluate the spatial and temporal behaviors of seismic activity, some important seismotectonic parameters can be used. The parameters used in the scope of this study can be given as (1) *b*-value which describes the power-law distribution of earthquakes, (2) *Dc*-value which implies the number of objects greater than a specified size and has a power law dependence on the size, and (3) *Z*-value which is one of the statistical parameters frequently used for analyzing the seismicity rate changes.

Seismically active fault regions are complex natural systems and they exhibit scale-invariant or fractal correlation between earthquakes in space and time (Öncel et al., 1995). Fractal dimension *Dc*-value describes the heterogeneity degree of seismicity in active fault system and some geological, mechanical or structural variations in heterogeneity. Thus, the higher order fractal dimension is increasingly sensitive for the distribution of magnitudes (Öztürk, 2011). Estimating of *b*-value refers a fractal correlation between frequency of earthquake and the seismic moment, energy, or fault length. The *b*-value for a region does not reflect only the relative proportion of the number of strong and small earthquakes in the region, but is also related to the stress condition over the region. Consequently, *b*-value is one of the most widely used seismicity parameters describing the size scaling behavior of earthquakes. In various parts of the world, a large number of studies on seismic quiescence analysis have been made in order to detect to precursory anomalies of a specific region. Wiemer and Wyss (1994) defined the precursory quiescence hypothesis in the following way: "*A statistically significant decrease of the seismicity rate that occurs in a restricted segment of a seismogenic zone. The rate decrease is terminated by a main shock and the quiescent volume covers all or a major part of the source volume.*" So, particular space-time seismicity occurrences that include the seismic quiescence phenomenon can be related to the seismotectonic processes that lead to earthquakes.

Turkey is a seismically very active region and therefore numerous statistical and physical studies have been carried out in order to examine the seismicity characteristics for seismic hazard assessments in many parts of Turkey, especially in the Western Anatolian region (e.g., Polat et al., 2008; Öztürk et al., 2008; Sayıl and Osmanşahin, 2008; Öztürk, 2012). However, detailed studies that represent possible correlations between fault distribution and seismicity are limited. It is well known that the Aegean extensional region is one of the most seismically active and rapidly prolongating areas of the Eastern Mediterranean region (Bozkurt, 2001). So, this region was struck by many strong and destructive earthquakes in the past. Therefore, some potential applications to spatial and temporal behaviors of fractal associations between seismotectonic arguments may provide important contributions for assessments of earthquake occurrences. Statistical scaling properties of seismicity patterns may have a potential at least to be sensitive short term predictors of major earthquakes.

Therefore, the principal aim of this study is to analyze the spatial and temporal behavior of seismicity in order to reveal the future earthquake potential in the Western Anatolian region. For this purpose, spatial and temporal assessments of the size-scaling distributions for this high-risk region are made by using some parameters such as seismotectonic *b*-value, fractal dimension *Dc*-value, completeness magnitude *Mc*-value and precursory seismic quiescence *Z*-value. In the finally, an up-to-date and a reliable empirical relation between *b*-value and *Dc*-value are presented for the Western Anatolian region of Turkey.

2. Seismotectonic Structure and Zonation in the Western Anatolian Region

The Western Anatolian graben systems and Aegean arc are one of the most important tectonic structures and seismically active fault regions in the Western Anatolia. In the Eastern Mediterranean, there is a convergence between Anatolian and African plates caused by subduction of Cyprus and Aegean arcs, where the African plate is subducting beneath the Anatolian Plate in north-northeast direction (Bozkurt, 2001). In the geodynamical evolution of the Aegean extension region, the Aegean arc has an important effect. The nature and structure of this region vary along the Aegean arc system and the eastern part of this system shows a transform fault characteristic. In addition, the dextral strike slip faulting mechanism associated with the North Anatolian Fault continues across the northern Aegean, crosses northern and central mainland Greece as a broad shear and eventually links up with the Hellenic subduction zone. This fault zone is also characterized by several second order faults that splay into the Anatolian Plate (Bozkurt, 2001). In Eastern Anatolia, there is convergence between the Eurasian and Arabian plates and as a result of this movement the Anatolian plate moves to the west along the North Anatolian Fault Zone and the East Anatolian Fault Zone. The Anatolian Plate moves anti-clockwise with a mean velocity of 24 mm/yr and this process continues along the Aegean in the southwestern direction (McClusky et al., 2000). Oral et al., (1995) stated that continental extension rate is approximately 30-40 mm/yr in the north-south direction.

As shown in Figure 1, the most important faults in the Western Anatolian region are Bakırçay, Kütahya, Gediz, Simav, Küçük Menderes and Büyük Menderes (east-west trending), Dinar, Alaşehir and Akşehir-Afyon (northwest-southeast trending), Burdur, Acıgöl, Çivril, Sandıklı-Dombayova (northeast-southwest trending), Soma, Zeytindağ-Bergama (north-south trending). These active faults show mainly normal faulting mechanism. The Western Anatolian extensional region has experienced many strong and destructive earthquakes during historical and instrumental epochs. Some of these earthquakes are 18 November 1919 Soma (*M*=6.9), 31 March 1928 Torbalı (*M*=6.3), 22 September 1939 Dikili-Bergama (*M*=6.5), 6 October 1942 Edremit Körfezi–Ayvacık (*M*=6.8), 16 July 1956 Söke–Balat (*M*=7.1), 28 March 1969 Alaşehir (*M*=6.5), 28 March 1970 Gediz (*M*=7.2), 11 October 1986 Çubukdağ (*M*=5.5) , 6 November 1992 Seferihisar-İzmir (*M*=6.0), and 10 April 2003 Seferihisar-İzmir (*M*=6.1) earthquakes.

The seismotectonic boundaries of the study area are updated from Öztürk (2012). Turkey is divided into 55 different source zones in Öztürk (2012) by taking into consideration the zonation studies by Erdik (1999) and Bayrak et al., (2009). Erdik et al., (1999) defined 37 source zones using all the available published data. In contrast, Bayrak et al., (2009) divided Turkey into 24 different source regions considering the different zonation studies given above for seismic hazard modeling in Turkey and solution of focal mechanism given by TUBITAK Marmara Research Center (Scientific and Technological Research Council of Turkey) for the great earthquakes that occurred in Turkey between 1977 and 2002, and plotting the existing tectonic structure with the epicenter distribution of earthquakes. So, some parts of these seismogenic zones for the Western Anatolian region are considered as the study

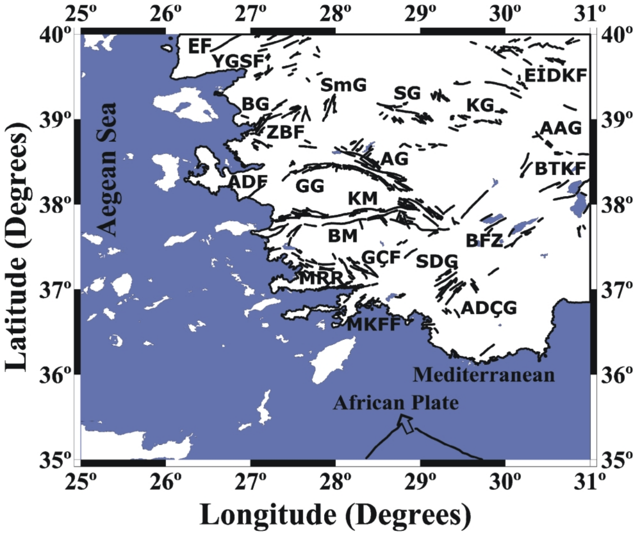

Figure 1: Major tectonic structures in the Western Anatolian region. Principle faults were modified from Şaroğlu et al., (1992) and Bozkurt (2001). Names of the faults: EF: Etili Fault, YGSF: Yenice-Gönen and Sarıköy Faults, BG: Bakırçay Graben, SmG: Soma Graben, SG: Simav Graben, KG: Kütahya Graben, EİDKF: Eskişehir, İnönü-Dodurga and Kaymaz Faults, ZBF: Zeytindağ-Bergama Faults, ADF: Aliağa and Dumlupınar Faults, GG: Gediz Graben, AG: Alaşehir Graben, AAG: Akşehir-Afyon Graben, BTKF: Beyşehir, Tatarlı and Kumdanlı Faults, KM: Küçük Menderes, BM: Büyük Menderes, BFZ: Burdur Fault Zone, SDG: Sandıklı and Dombayova Grabens, MRR: Muğla and Rhodes Region, GÇF: Gölhisar and Çameli Faults, MKFF: Marmaris, Köyceğiz and Fethiye Faults, ADÇG: Acıgöl, Dinar and Çivril Faults

regions. In addition, a few new smaller zones are added in order to compare the different tectonic structures in details in the same regions. Consequently, the Aegean extensional region of Turkey limited by the coordinates 25°N and 31°N in latitude and 35°E and 40°E in longitude is divided into 18 new seismotectonic subregions. Detailed tectonic structures are modified from Şaroğlu et al., (1992) and Bozkurt (2001). Major tectonics and selected 18 new seismic source zones in the Western Anatolian region are shown in Figures 1 and 2, respectively.

3. Earthquake database

The local magnitude, M_L, is one of the various types of magnitudes to calculate the quantitative size of the earthquakes. Magnitudes of earthquakes are actually based on the amplitude of ground motion displacement as measured by a standard seismograph. The Richter magnitude is one of best known among them and it was originally defined for local events for the southern California. M_L is often used by local seismic network and given a formula by Richter (1935; 1938) as in the following:

$$M_L=Log_{10}A(\Delta)-Log_{10}A_0(\Delta)+C \qquad (1)$$

Where $A(\Delta)$ is the maximum earthquake amplitude in millimeters recorded on the standard Wood-Anderson torsion seismograph which has a static magnification of 2800, a damping factor 0.8, and a natural period of 0.8 second at an epicentral distance Δ in kilometers. A_0 describes the loss of energy with respect to distance such as geometrical spreading, anelastic attenuation due to the local geology. C is an empirical correction for the particular station or instrument used and it is strongly depended on the local geology. However, this magnitude scale has also been used in the other seismic network in the world to determine the local magnitude because it is presumed that the Richter's southern California $Log_{10}A_0$ has the similar properties in the crust and mantle.

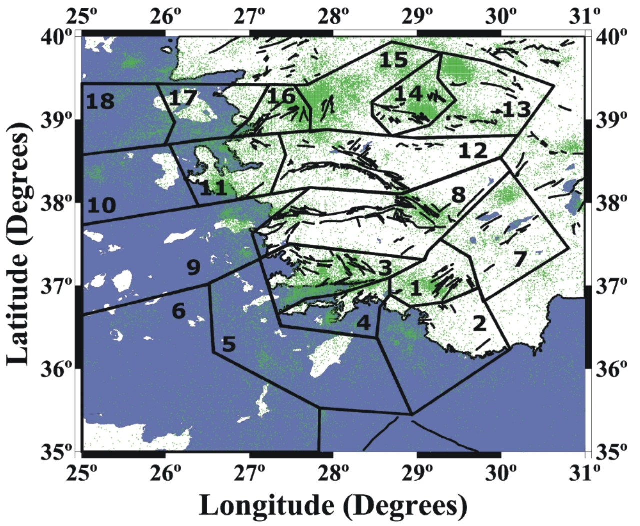

Figure 2: Seismotectonic zones and the epicenters of 79,881 earthquakes with M_D≥1.0 between 1970 and 2014

A few earthquake databases are available for Turkey from both national and international catalogs. The database used in this study is taken from Öztürk (2009) for the time period between 1970 and 2006 (all details for the relationships of different magnitude types can also be found in Bayrak et al., 2009). He used some empirical relationships in order to prepare a complete and homogeneous earthquake catalog, and prepared an instrumental database for duration magnitude M_D including 73,530 earthquakes between 1970 and 2006. The Bogazici University, Kandilli Observatory and Research Institute (KOERI) catalog is also used for the data from 2006 to 2014. KOERI generally provides the type of M_D for all earthquakes, especially after 2000. However, KOERI usually gives local magnitude M_L for missing MD in recent years. In such a case that M_D is unknown in KOERI catalog from 2006 to 2014; calculations of unknown M_D are made by using M_D-M_L relationships (Table 1) given in Öztürk (2009). 76,735 earthquakes are finally obtained in and around Turkey from 2006 to 2014. Thus, 150,265 earthquakes are obtained in totally for all regions of Turkey between 1970 and 2014.

After the selection of the Western Anatolian region as the study area, the earthquake catalog for this region is prepared. In this stage, the earthquakes from 1970 to 2014 are selected for the studied region from whole catalog. The type of magnitude used in this study is M_D and the study catalog is complete for the whole study period and for all magnitude levels. Thus, the final data catalog is prepared in the time period from 6 January 1970 to 31 December 2013, the time interval of about 43.98 years. Finally, there are in total 79,881 events with magnitudes larger than or equal 1.0 in this coordinates during 1970- 2014. Epicenter locations of all earthquakes for M_D≥1.0 in the Western Anatolian region for this time inter-val are also shown in Figure 2.

4. Brief Descriptions of the Statistical Methods

In the scope of this study, a few statistical arguments such as seismotectonic parameter *b*-value of Gutenberg-Richter (*G-R*) relation, fractal dimension *Dc*-value and seismic quiescence *Z*-values are analyzed as the spatial and temporal variations of seismicity in the Western Anatolian Region.

4.1 Gutenberg-Richter relation (*b*-value) and magnitude completeness (*Mc*-value)

The relation between magnitude and frequency of occurrence of earthquakes was described by Gutenberg-Richter (1944) as in the following equation

$$\log_{10}N(M)=a-bM \qquad (2)$$

where $N(M)$ is the expected number of earthquakes with magnitudes equal to or greater than M, *b*-value describes the slope of the magnitude-frequency distribution, and *a*-value is proportional to the activity rate of seismicity. *a*-value changes from region to region. These variations depend on the obser-

Region Number	Earthquakes Number	Empirical relations	Correlation Coefficient
1	20	MD = 0.881(±0.138)*ML+0.596(±0.286)	0.820
2	14	MD = 0.919(±0.023)*ML+0.292(±0.048)	0.996
3	11	MD = 0.991(±0.080)*ML+0.033(±0.158)	0.966
4	24	MD = 0.768(±0.114)*ML+1.004(±0.239)	0.808
5	4	-	-
6	26	MD = 0.816(±0.068)*ML+0.825(±0.147)	0.920
7	14	MD = 0.812(±0.112)*ML+0.726(±0.234)	0.889
8	2	-	-
9	11	MD = 0.432(±0.339)*ML+2.293(±0.675)	0.359
10	23	MD = 0.843(±0.066)*ML+0.580(±0.137)	0.935
11	81	MD = 0.818(±0.036)*ML+0.586(±0.075)	0.929
12	46	MD = 1.277(±0.209)*ML-1.372(±0.434)	0.669
13	12	MD = 1.113(±0.389)*ML-0.555(±0.768)	0.636
14	29	MD = 0.956(±0.057)*ML+0.103(±0.114)	0.952
15	70	MD = 0.934(±0.029)*ML+0.163(±0.062)	0.967
16	15	MD = 0.446(±0.146)*ML+1.900(±0.291)	0.619
17	67	MD = 0.748(±0.043)*ML+0.869(±0.089)	0.903
18	12	MD = 0.886(±0.044)*ML+0.349(±0.087)	0.985
19	18	MD = 0.901(±0.049)*ML+0.268(±0.100)	0.974
20	62	MD = 0.939(±0.068)*ML+0.091(±0.138)	0.867
21	22	MD = 0.876(±0.069)*ML+0.450(±0.139)	0.939
22	17	MD = 0.873(±0.043)*ML+0.467(±0.089)	0.980
23	11	MD = 1.229(±0.691)*ML-0.707(±1.382)	0.473
24	21	MD = 0.743(±0.099)*ML+1.211(±0.222)	0.851

Table 1: M_D and M_L relations for 24 different seismotectonic zones of Turkey. The values in the parentheses show the uncertainties (from Öztürk, 2009)

vation period, length of the study area and also size of earthquakes. Utsu (1971) stated that parameter *b* varies roughly between 0.3 and 2.0, depending on the different regions. However, the changes in *b*-value can be caused by many factors such as the number of small and great events, geological complexity and degree of heterogeneity of cracked medium, strain and stress condition in the region (e.g., Schorlemmer et al., 2005). The regional scale estimates of *b*-value are approximately equal to 1 on average (Frohlich and Davis, 1993).

Completeness magnitude *Mc* is an important parameter in many seismicity studies, especially in investigation of magnitude-frequency relation. The power law distribution of *G-R* against magnitude is used in order to estimate *Mc*-value. The variation in *Mc*-value is calculated using a moving time window approach (Wiemer and Wyss, 2000). If the completeness magnitude changes systematically as a function of time and space, temporal variations of *Mc*-value can cause potential wrong value of seismicity parameters, primarily in b-value. Thus, *Mc* analysis of the catalog used in this study is an im-portant process since a part of this study uses *Mc*-value in the estimation of *b*-value.

4.2 Fractal dimension (*Dc*-value)

To evaluate the size scaling attributes and clustering properties of seismotectonic arguments, fractal analysis is often used. Spatial and temporal patterns of earthquake occurrence are demonstrated to be fractal using the two-point correlation dimension *Dc*. Correlation dimension *Dc* and the correlation sum *C*(*r*) was defined by Grassberger and Procaccia (1983) as in the following equations:

$$Dc=\lim_{r\to 0}[\log C(r)/\log r] \tag{3}$$

$$C(r)=2N_{R<r}/N(N-1) \tag{4}$$

where *C*(*r*) is the correlation function, *r* is the distance between two epicenters and *N* is the number of events pairs separated by a distance *R*<*r*. If the epicenter distribution has a fractal structure, following relation is obtained:

$$C(r)\sim r^{Dc} \tag{5}$$

where *Dc* is a fractal dimension, more strictly, the correlation dimension. The distance *r* (in degrees) between two earthquakes is calculated from:

$$r=\cos^{-1}(\cos\Theta_i\cos\Theta_j+\sin\Theta_i\sin\Theta_j\cos(\Phi_i-\Phi_j)) \tag{6}$$

where (Θ_i,Φ_i) and (Θ_j,Φ_j) are the latitudes and longitudes of the ith and jth events, respectively (Hirata, 1989). By plotting *C*(*r*) against *r* on a double logarithmic coordinate, fractal dimension *Dc* is practically obtained from the slop of the graph.

Fractal dimension characterized the nature of spatial and temporal properties of the earthquakes. *Dc* is calculated to evaluate the possible unbroken sites and seismic gaps, which may be broken in future (Kagan, 2007). In other words, the fluctuations in fractal properties principally depend on the complexity or quantitative measure of the degree of heterogeneity of seismic activity. Higher *Dc*-values associated with lower *b*-values are the dominant structural feature in the areas of increased complexity in the active fault system and it may be caused due to clusters. Thus, this property may be an indication of stress changes on fault planes of smaller surface area (Öncel and Wilson, 2002; Polat et al., 2008).

4.3 Declustering of earthquake catalog and definition of the seismic quiescence method (Z-value)

The algorithm of cluster analysis "declusters" or decomposes an earthquake catalog into main and secondary events (Arabasz and Hill 1996). This process removes all dependent events from each cluster and substitutes them with a unique event. Eliminating the dependent events from the catalog is necessary for a quantitative seismic quiescence analysis. In this study, ZMAP software introduced by Wiemer (2001) is used to decluster the earthquake catalog based on the algorithm developed by Reasenberg (1985) and this declustered catalogue is used for making seismic quiescence analysis. In recent years, there were a considerable number of investigations of seismic quiescence phenomena by using ZMAP software (e.g., Wyss et al. 2004, Polat et al. 2008; Öztürk, 2011; 2013; Öztürk and Bayrak, 2012).

There are 79,881 events with magnitudes equal to or larger than 1.0 in the catalog. Average *Mc*-value for whole study region from 1970 to 2014 was calculated as 2.8 and the number of events with magnitude M_D<2.8 are obtained as 35,043. All events with magnitude M_D<2.8 are subtracted from the catalog and thus, the number of earthquakes exceeding this magnitude threshold is found as 44,838. Using the declustering algorithm, 8973 (about 20%) earthquakes are subtracted and about 55% of all earthquakes in totally were taken away from the catalog. Thus, the number of events for *Z*-test in the Western Anatolian region was reduced to 35,865 with M_D≥2.8.

There are many techniques describing the seismicity rate change and most of them use the phenomenon of seismic quiescence and the most frequently used is the standard deviate *Z*-test. *ZMAP* technique is used in order to image the regions displaying seismic quiescence (for details see Wiemer and Wyss, 1994). *Z*-test generates the long term average, $LTA_{(t)}$, function for the statistical evaluation of the confidence level in units of standard deviations:

$$Z=(R_1-R_2)/(S_1^2/N_1+S_2^2/N_2)^{1/2} \tag{7}$$

where R_2 is the mean seismicity rate in the foreground window, R_1 is the average number of earthquakes in the whole background period, *S* and *N* are the standard deviations and the number of samples, within and outside the window. The *Z*-value computed as a function of time, letting the foreground window slide along the time duration of catalogue, is called LTA.

5. Results of Spatial and Temporal Analyses and Discussions

In the scope of this study, the Western Anatolian region is divided into 18 different seismotectonic zones to make a detailed statistical analysis among two seismotectonic parameters, *b* and *Dc*-values. The calculation of *b* and *Dc*-values for 18 regions is carried out using *ZMAP* software (Wiemer, 2001). The maximum likelihood method is used in order to calculate the *b*-values, because it yields a more robust estimate than the least-square regression method (Aki, 1965). The *Dc*-values for all parts of the Western Anatolian region are obtained with 95% confidence limits by linear regression.

Mc usually shows a non-stable value in time and has a great importance for many seismic studies. It is very important to use the maximum number of earthquakes for high quality results in seismicity analyses. In this study, the change of *Mc*-value as a function of time is estimated by using a mowing window approach with maximum curvature method (Woessner and Wiemer, 2005). The whole earthquake catalog containing all 79,881 events with M_D≥1.0 is included in the estimation of *Mc*-value and it is plotted with its standard deviation for samples of 250 events/windows. Figure 3 shows the changes in *Mc*-value with time. *Mc*-value is rather large and varies from 3.5 to 4.5 until 1975 whereas it changes from about 3.5 to about 2.5 between 1975 and 1990. *Mc* has a value between 2.7 and 3.0 from 1990 to 2010. Then, *Mc*-value is smaller than 2.7 after 2010. It can be easily seen that *Mc*-value changes between 3.0 and 2.5 after 2000. As a result, *Mc*-value for the Western Anatolian region varies between 2.5 and 3.0 and this value is compatible with the results of Polat et al., (2008).

Figure 4 shows the cumulative number of events versus time for the original catalog including all dependent 79,881 events with M_D≥1.0 and for the declustered catalog including 35,865 independents events with M_D≥2.8 between 1970 and 2014. As shown in Figure 4, there is no significant seismic activity from 1970 to 1976 and a little seismicity change between 1976 and 1995. On the contrary, there are great seismic changes after 1995. The cumulative earthquake number of declus-

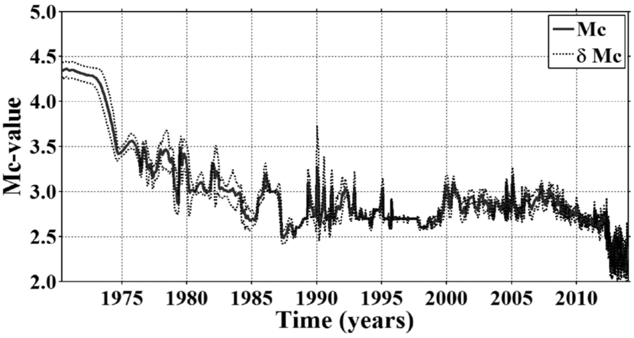

Figure 3: Variations of magnitude completeness *Mc*-value from 1970 to 2014 in the Western Anatolian region. Standard deviation (δ*Mc*) of the completeness (dashed lines) is also given. *Mc* is plotted for overlapping samples, each containing 250 events

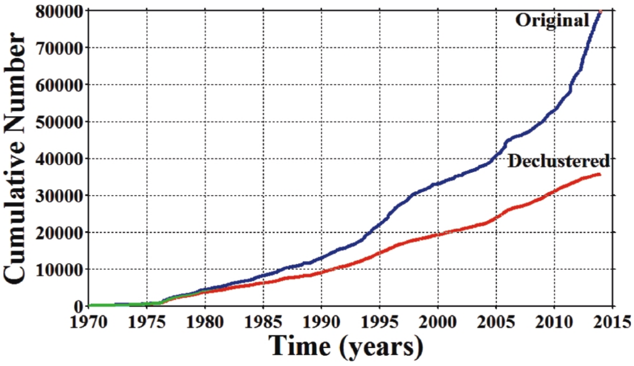

Figure 4: Cumulative number plots of the earthquakes versus time for all events with M_D≥1.0 and declustered events with M_D≥2.8 in the Western Anatolian region

tered catalog with M_D≥2.8 as a function of time for the Western Anatolian region has a smoother slope when compared to the original catalog. Thus, it is clear from Figure 4 that declustering algorithm has removed dependent events from the original catalog and after processing the declustering algorithm, a more homogeneous, reliable and robust earthquake catalog has been obtained.

The resulting values of two seismotectonic parameters for all tectonic subregions are shown in Table 2: *b*-value changes between 0.97 and 1.95; b-values smaller than 1.0 are found in regions 7 and 13, including Burdur Fault zone and Kütahya graben. Moderate values around 1.0 are calculated along the Aliağa and Dumlupınar Faults, Aegean Arc and region 18 (western sea part of Bakırçay graben). The highest *b*-value is calculated as 1.93 in region 16, including Zeytindağ-Bergama faults. Other high values above 1.5 are estimated in regions 5, 15 and 17 - these regions are related to the Muğla and Rhodes region, Soma and Bakırçay grabens. The *b*-values obtained for the rests of the subregions range from 1.2 to 1.5. Regional distribution of *b*-value is also plotted at every node of the 0.05° grid (Fig. 5). As for changing *Mc*-values, variations in b-values are estimated by using a moving window approach. Declustered earthquake catalog with M_D≥2.8 is included in the estimation of b-value with samples of 500 events/windows. As stated in Frohlich and Davis (1993), average b-value estimation is approximately equal to 1.0. The Western Anatolia is an extensional zone and has relatively large *b*-values since the stress is more easily reduced caused by great number of small earthquakes and this situation can be explained by large heterogeneity (Polat et al., 2008), low stress distribution due to high heat flow (İlkışık, 1995). According to Scholz (1968), lower *b*-values indicate higher stress release. Consequently, low *b*-values in the Burdur Fault zone and Kütahya graben may be an indication of low degree of heterogeneity, high-strain due to the subduction tectonics and stress to build up over time and to be released by earthquakes that are less frequent but great in magnitude (Öncel and Wilson (2002). In the regions where larger b-values are estimated, however, this situation may be considered as an indication of low stress release by a large number of small earthquakes and thus geological complexity is very high (Lopez Casado et al., 1995). As a general result, estimated b-values through the maximum likelihood approach for the G-R method seem to have a good relation to the tectonics and seismic activity. Thus, special interest should be given to the regions where low *b*-values are observed.

Fractal dimension *Dc*-value varies from 2.11 to 2.51 for all 18 seismotectonic subregions as seen in Table 2. *Dc*-values are below 2.3 in regions 5, 12, 14 and 16. These regions cover Muğla and Rhodes, Gediz, Alaşehir and Simav grabens, and Zeytindağ-Bergama faults. *Dc*-values changing between 2.3 and 2.4 are obtained in regions 1, 2, 3, 8, 9, 10, 15 and 17 which includes Sandıklı and Domboyova grabens, Acıgöl, Dinar, Çivril, Gölhisar ve Çameli faults, Büyük and Küçük Menderes grabens, western part of Aliağa and Dumlupınar faults, Soma and Bakırçay grabens. In all the remaining regions, *Dc*-values fluctuate between 2.4 and 2.5 (regions 4, 6, 7, 11, 13, 18). These zones are related to Marmaris, Köyceğiz and Fethiye faults, Aegean Arc, Burdur fault zone, Aliağa and Dumlupınar faults. Estimated *Dc*-values in the Western Anatolia are generally higher than 2.2. As in *b*-value map (Fig. 5), the regional distribution of *D*c-values is also plotted at every node of 0.05° grid (see Fig. 6). These results reveal that the earthquake distribution becomes less clustered (higher *Dc*-value) since the probability of strong earthquakes becomes smaller (larger *b*-value) and this indicate that, in general, there is greater fracture

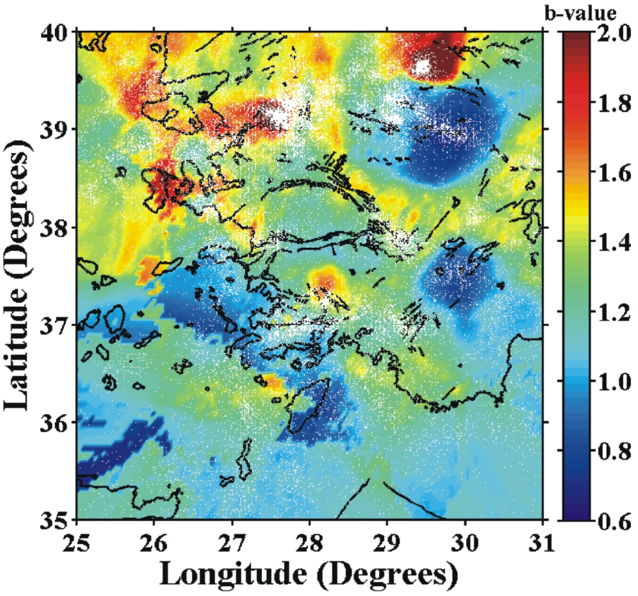

Figure 5: Spatial distribution of seismic *b*-value for the Western Anatolian region. White dots show the declustered earthquakes with M_D≥2.8

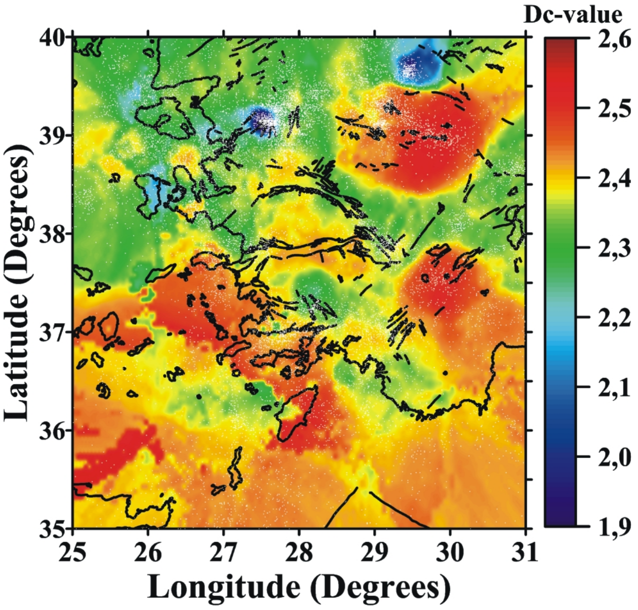

Figure 6: Spatial distribution of fractal dimension *Dc*-value for the Western Anatolian region. White dots show the declustered earthquakes with M_D≥2.8

toughness in all parts of the Western Anatolia. Barton et al., (1999) stated that the faults where earthquakes are caused by failure of isolated, small asperities and occurred in clusters, are related to the higher *b*-value and lower *Dc*-value. The higher order fractal dimension (especially greater than 2.3) is increasingly sensitive to heterogeneity in the distribution of magnitudes. This suggests that seismicity is more clustered at larger scales (or in smaller areas) in these regions. However, there are only two regions whose *b*-values are smaller than 1.0 and in addition, higher *Dc*-values larger than 2.4 are estimated in these zones. As stated above, these zones are related to the Burdur fault zone (region 7) and Kütahya graben (region 13). Öncel and Wilson (2002) stated that, in the regions of increased complexity in the active fault system (higher *Dc*-value) associated with lower *b*-value, the stress release occurs on fault planes of smaller surface area. As a result, it is reasonable to assume that the higher *Dc* values (≥2.4) and lower b-values (≤1.0) are the dominant structural feature in the study area and may arise due to clusters since the uniform distribution of events decreases with an increase in the clustering of earthquakes.

To determine a reliable and suitable statistical relationship between two seismotectonic parameters *b* and *Dc*-values for the Western Anatolia, the orthogonal regression (Carrol and Ruppert, 1996) is used since the standard least square method is based on the assumption that horizontal axis values are estimated without error. Figure 7 shows the relationship of orthogonal regression fit between *b* and *Dc*-values. Also, *Dc*-value versus b-value for orthogonal regression method with fit curve, corresponding equation and, 95% confidence interval are given (Fig. 7). Negative correlation coefficient (*r*) is calculated as 0.73 and it can be accepted as a strong enough value. There are 13 earthquakes within the confidence limit of the regression. Linear regression fit is used and following relationship is obtained:

$$Dc=2.74-0.29*b,\ (r=0.73) \tag{8}$$

Many examples of previous studies on the correlation between *Dc* and *b*-values can be found for different parts of the world (e.g., Aki, 1981; Hirata, 1989; Öncel et al., 2001; Roy, et al., 2011) and Turkey (e.g., Öncel et al., 1995; 1996; Öncel and Wilson, 2002; 2007; Öztürk, 2012). Since Aki (1981) suggested a simple relationship between *b* and *Dc*-values with a positive correlation $D=3b/c$ (where c is a constant determined from the slope of the log moment versus the magnitude relation, *c* is normally taken as 1.5), both positive (e.g., Öncel and Wilson, 2004; Roy et al., 2011) and negative (e.g., Hirata, 1989, Öncel et al., 1995; 1996) correlations between these two seismotectonic parameters have been reported for different parts of the world and Turkey.

Hirata (1989) pointed out that Aki's fractal dimension corresponds to the capacity dimension and may be compared with the correlation dimension. Hirata's (1989) result do not support Aki's speculation that $D=3b/c$, on the contrary, there is a negative correlation as $Dc=2.3-0.73*b$ (with $r=-0.77$) between b and fractal dimension of epicenters in the Tohoku region of Japan. Similarly, a study of seismicity in the North Anatolian Fault Zone (NAFZ), Turkey, revealed a long- term negative correlation between *b* and *Dc* (Öncel et al., 1995). The *b*-value is found to be weakly negatively correlated with fractal dimension as $Dc=2.74-1.52*b$ (with $r=-0.56$) for the NAFZ (including the northern Aegean sea) in Öncel et al., (1995). Also, Öncel et al., (1996) investigated the nature of temporal variations in the statistical properties of seismicity associated with the NAFZ during the instrumental period 1900-1992 and observed a strong negative correlation ($r=-0.85$) between *Dc* and *b*-values as $Dc=2.32-1.09*b$. In contrast, Öncel and Wilson (2002) made an analysis that is restricted to the NAFZ. They found a weak positive correlation ($r=0.48$) between variations in *b* and *Dc* in the western NAFZ. Analysis presented in Öncel and Wilson (2004) reveals a strong positive correlation ($r=0.81$) between Dc and *b*-values along the NAFZ during the 1981 to 1998 time period preceding the 1999 Izmit earthquake. Öncel and Wilson, (2007) observed a strong positive correlations between *Dc* and *b*-value during the 1992-1994.4 ($r=0.84$) and 1996.6-1998.2 ($r=0.94$) and negative correlation ($r=-0.71$) extending from approximately mid-1994 to mid-1996 in the northwestern Turkey between 40.5° to 41° north latitude, and 29° and 31° east longitude. Consequently, estimated relation, correlation coefficient and the number of events in the confidence limit from orthogonal regression provides a reliable

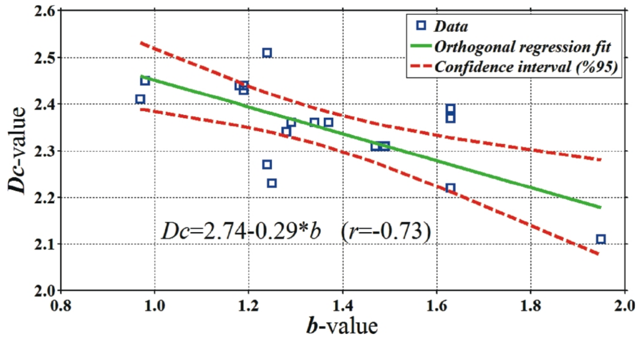

Figure 7: Orthogonal regression fit, confidence interval, corresponding equation and correlation coefficient for the relationship *b*-value and *Dc*-value for the Western Anatolian region. There are 13 events in the confidence interval

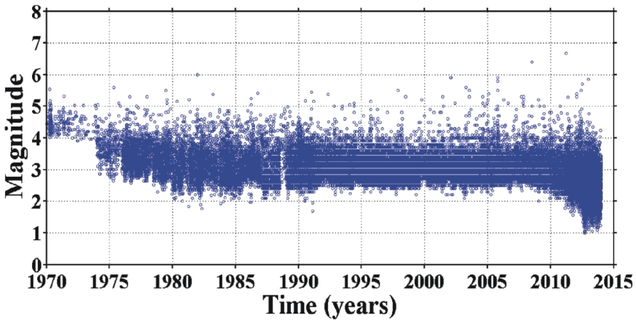

Figure 8: Magnitude distribution as a function of time for earthquakes occurred in the Western Anatolian region from 1970 to 2014

Region	Tectonic Environments	Earthquake Numbers	*Mc* value	*b*-value	*Dc*-value
1	Sandıklı and Dombayova Grabens and Acıgöl, Dinar and Çivril Faults	2550	2.9	1.29±0.05	2.36±0.03
2		2043	3.0	1.47±0.09	2.31±0.03
3	Gölhisar and Çameli Faults, Marmaris, Köyceğiz, Fethiye Faults and Muğla and Rhodes Region	7532	3.0	1.49±0.05	2.31±0.05
4		2625	2.8	1.24±0.06	2.51±0.03
5		2347	3.5	1.63±0.09	2.22±0.02
6	Aegean Arc	1751	3.5	1.19±0.07	2.43±0.02
7	Burdur Fault Zone	2039	2.8	0.98±0.05	2.45±0.03
8	Büyük and Küçük Menderes Grabens	4236	2.9	1.28±0.07	2.34±0.03
9		2650	2.9	1.37±0.06	2.36±0.03
10	Aliağa and Dumlupınar Faults	1053	3.1	1.34±0.06	2.36±0.03
11		4777	3.1	1.18±0.12	2.44±0.02
12	Gediz Graben and Alaşehir Graben	2402	2.8	1.25±0.05	2.23±0.01
13	Kütahya Graben	7684	2.6	0.97±0.15	2.41±0.03
14	Simav Graben	8351	2.8	1.24±0.05	2.27±0.06
15	Soma Graben	9123	2.7	1.63±0.05	2.37±0.02
16	Zeytindağ-Bergama Faults	6790	2.7	1.95±0.06	2.11±0.03
17	Bakırçay Graben	2237	3.0	1.63±0.07	2.39±0.02
18		1574	3.3	1.19±0.04	2.44±0.04

Table 2: Seismotectonic parameters *b* and *Dc*-values with their standard deviations as well as the number of earthquakes and completeness magnitudes for all tectonic subregions in the Western Anatolian region

assessment for the seismotectonics of the Western Anatolian region. Also, this equation is basically similar to the results presented in the literature.

The seismotectonic parameters b and Dc-values as well as the numbers of earthquakes, minimum (M_{min}) and maximum (M_{max}) magnitudes, Mc-values and, a-values for every one year are given in Table 3. In order to make an assessment on the seismic activity with time, temporal distribution of all $M_D \geq 1.0$ earthquakes from 1970 to 2014 is plotted as seen in Figure 8. As shown in Table 3, there are a few strong earthquakes larger than 5.5 from 1970 to 2000. But further on, significant fluctuations in seismic activity are recorded after year 2000. Magnitude-time histogram indicates great seismic changes in the number of strong events especially from 2005. The seismic activity related to the clustering properties is clearly observable and this situation may correspond to a main event in the region. In addition, temporal clustering characteristic of the seismic activity related to the major events is strong enough for many earthquakes in which occurred 1975, 1981, 1997, 2002, 2003, 2005, 2008, 2011, 2012 and 2013. Temporal changes in *b* and *Dc*-values versus time are plotted in Figure 9. These variations as a function of time are estimated to investigate the possible temporal changes during the time period 1970 and 2014. While *Dc*-values show a strong increasing trend before some certain years, *b*-values show a strong decreasing trend in the same years. Also, these fluctuations can be clearly seen in Table 3 and from arrows on Figure 9. For example, *Dc*-value is increasing while *b*-value is decreasing from 1974 to 1975 and, a larger earthquake than that of 1974 occurred in 1975. Such kind of similar changes are also estimated between 1978 and 1979, 2000 and 2001, 2004 and 2005, 2006 and 2007. However, such kinds of changes are not observed from 1997 to1998 and from 2011 to 2012. Many factors can cause perturbations of these parameters as mentioned above. In active fault system, stress release occurs on fault planes of smaller surface area since the higher *Dc*-values are associated with lower *b*-value. The higher order fractal dimension is increasingly sensitive to heterogeneity in the distribution of magnitudes. This suggests that seismicity is more clustered at larger scales (or in smaller areas) in the West Anatolian region.

In order to map the spatial distribution of the *Z*-value, the study area is firstly divided into rectangular cells spacing 0.05º in latitude and longitude. The nearest earthquakes, *N*, at each node are taken as 50 events. Then, the changes in seismic activity rate are searched within a maximum radius changes by a moving time window T_w (or iwl), stepping forward through the time series by a sampling interval as described by Wiemer and Wyss (1994). In order to have a continuous and dense coverage in time, population of the events is binned into many binning spans of 28 days for each grid point. T_w=5.5 years are used as the window length because the quiescence areas are better visible for a window of 5.5 years.

Regional variations of *Z*-value with T_w=5.5 years is plotted in Figure 10. The length of T_w for *Z*-value map is calculated by adding T_w-value to the time chosen as the beginning of the time cut as indicated in top of the Figure 10. Thus, *Z*-value map is plotted for the beginning of 2014. Some clear seismic quiescence regions in the Western Anatolia are defined. These anomalies regions are pointed out around and in the northeast of Simav fault (region 14), between Soma (region 15) and Bakırçay grabens (region 17), around Aliağa-Dumlupınar faults (region 11) and Alaşehir graben (region 12), in the western end of Gediz graben (region 12), in the junction of Gediz, Küçük and Büyük Menderes grabens (region 8), between Gölhisar-Çameli faults and Muğla-Rhodes region (region 3), around

Acıgöl, Dinar, Çivril faults (region 2), in the southeastern part of the Zeytindağ-Bergama faults (junction of regions 11 and 12), between Sandıklı-Domboyova grabens (region 1) and Burdur fault zone (region 7).

In addition to above-mentioned quiescence areas, there are a few anomalies in the western part of the study area. One of them is found centered at the coordinates 39°N in longitude and 25°E in latitude, 38°N in longitude and 25°E in latitude and nearly 37°N in longitude and 26°E in latitude. These areas are in the sea part of the Western Anatolian region, which has no fault system (regions 10 and 18). These values can be interpreted as the artificial results from contouring or interpolations since there are fewer earthquakes in these regions. As stated in Joswig (2001), characterizing the null hypothesis should be made before the interpretation of the seismic quiescence maps. This means the fraction of success for earthquake predictions and it can be achieved by pure chance. Such kind of quiescence maps do not issue any alert but should help to relate quiescence spots to pending earthquakes. So, the null hypothesis describes how many quiescence anomalies would precede a real event, even if the earthquake distribution is completely random. The small scale quiescence anomalies in some regions can be interpreted as false alarms exceeding in significance the precursors. This randomness could be derived from the given catalogue by arbitrarily altering the event times, but keeping their locations for the spatial clustering (Joswig, 2001). Thus, such kind of heterogeneous reporting as a function of time can generate false alarms and impede reliable measurement of natural seismicity rate changes.

Polat et al., (2008) made an earthquake hazard assessment for the Aegean extension region of Turkey by using fractal behavior, Gutenberg-Richter *b*-value and seismic quiescence *Z*-value. They found some anomalous regions including Çandarlı Bay and Bergama-Zeytindağ fault zone, İzmir and Orhanlı faults zone and, Buldan and surrounding regions. They suggested that the sites of larger *Z*-values and smaller *b*-values can be considered to be the most likely regions for future earthquakes.

Year	Earthquake Numbers	M_{min}	M_{max}	*Mc*-value	*a*-value	*b*-value	*Dc*-value
1970	238	4.0	5.5	4.4	9.31	1.65±0.10	2.54±0.03
1971	91	4.0	5.3	4.2	7.98	1.57±0.04	2.46±0.03
1972	35	3.9	5.0	4.0	13.2	1.09±0.12	1.50±0.01
1973	28	3.9	5.0	4.2	7.11	1.40±0.30	1.50±0.01
1974	221	2.8	5.1	3.4	5.59	1.54±0.09	1.55±0.01
1975	166	2.7	5.6	3.5	5.67	1.21±0.07	1.64±0.03
1976	1241	2.6	5.3	3.5	7.86	1.48±0.06	1.77±0.02
1977	840	2.7	5.3	3.5	5.86	1.38±0.08	1.82±0.02
1978	562	2.3	4.9	3.4	7.35	1.66±0.11	1.97±0.02
1979	1016	2.2	5.5	3.4	6.70	1.20±0.04	2.03±0.03
1980	616	2.0	5.2	3.0	5.32	1.19±0.07	1.92±0.02
1981	697	1.8	6.0	3.0	5.26	1.17±0.05	2.13±0.07
1982	787	1.8	4.8	3.2	5.35	1.24±0.04	2.01±0.02
1983	599	1.9	5.4	3.0	5.10	1.19±0.09	2.00±0.03
1984	1062	2.0	4.9	2.8	4.90	1.14±0.10	1.92±0.04
1985	847	2.1	4.9	2.9	5.54	1.09±0.06	1.79±0.02
1986	1310	2.0	5.4	3.0	6.44	1.18±0.04	1.96±0.04
1987	597	2.1	4.7	2.8	4.32	0.77±0.10	1.52±0.03
1988	669	2.1	4.9	2.5	4.92	0.95±0.08	1.17±0.03
1989	1312	2.1	5.0	3.0	5.22	1.39±0.11	1.54±0.03
1990	1610	2.0	5.2	2.9	5.18	1.16±0.10	1.39±0.03
1991	1164	1.7	5.4	3.0	5.09	1.42±0.13	1.53±0.03
1992	1350	2.2	5.4	3.0	6.20	1.51±0.09	2.54±0.03
1993	2375	2.3	5.0	2.8	7.71	1.49±0.08	2.51±0.03
1994	2585	2.3	5.1	2.8	7.00	1.36±0.03	2.23±0.03
1995	3295	2.3	5.2	2.8	6.93	1.45±0.05	2.23±0.03
1996	2573	2.3	4.9	2.7	7.19	1.43±0.03	2.22±0.03
1997	2462	2.2	5.5	2.7	7.27	1.49±0.04	2.15±0.02
1998	1389	2.4	5.3	2.6	6.39	1.27±0.03	2.37±0.05
1999	1393	2.2	5.2	2.8	6.40	1.48±0.06	2.24±0.04
2000	1181	2.4	4.9	3.0	7.36	1.50±0.05	2.36±0.03
2001	1125	2.2	5.3	2.8	6.19	1.17±0.04	2.58±0.04
2002	1344	2.2	5.9	2.8	6.40	1.20±0.03	2.61±0.02
2003	1357	2.1	5.6	2.8	6.82	1.07±0.13	2.31±0.05
2004	2526	2.3	5.3	2.8	6.93	1.30±0.03	2.54±0.04
2005	4188	2.2	5.9	2.8	6.87	1.21±0.02	2.72±0.04
2006	1336	2.3	5.2	2.9	7.10	1.63±0.07	2.14±0.03
2007	1449	2.3	5.3	3.0	6.71	1.26±0.04	2.29±0.06
2008	2418	2.3	6.4	2.8	6.81	1.45±0.09	2.43±0.04
2009	2945	2.0	5.2	2.7	6.49	1.35±0.11	2.31±0.05
2010	3856	2.1	5.0	2.7	7.10	1.38±0.02	2.20±0.05
2011	6160	1.6	6.7	2.7	7.28	1.39±0.02	2.20±0.05
2012	8926	1.0	5.7	2.4	6.24	1.15±0.11	2.31±0.05
2013	7940	1.0	5.9	2.4	5.57	1.48±0.08	2.16±0.05

Table 3: *b* and *Dc*-values and some other seismic parameters such as the number of earthquakes, minimum magnitudes, maximum magnitudes and *a*-value as a function time for the Western Anatolian region

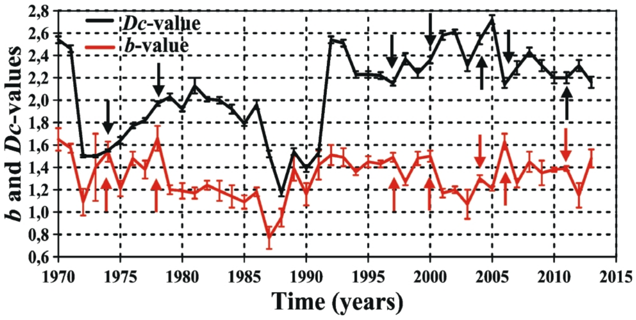

Figure 9: Variations of the seismotectonic parameters *b* and *Dc*-values as a function of time in the Western Anatolian region after 1970. Standard errors are also shown. Arrows indicate the beginning times of decreasing in *b*-value and increasing in *Dc*-value

This evidence can be explained with most promising environment where decrease in b-value is found with an increase in mean stress (Westerhaus et al., 2002). In this study, both the highest *b*-value and *Z*-value are observed in some regions including Simav and Alaşehir grabens, Gediz, Küçük Menderes and Büyük Menderes grabens, Gölhisar-Çameli faults and Muğla-Rhodes region, Acıgöl, Dinar, Çivril faults and, Sandıklı-Domboyova grabens. However, the lower *b*-values and the higher *Z*-values are observed in some regions including Burdur fault zone, Aliağa-Dumlupınar faults and Bakırçay grabens. Also, the findings and anomaly regions for *b* and *Z*-values in this study are more up-to-date and quite similar with those of Polat et al., (2008).

An investigation of the seismicity of Western Anatolia was made by Sayıl and Osmanşahin (2008), computing the parameters of Gutenberg-Richter *b*-value, seismic risk and recurrence period. According to their seismic risk estimations, the highest-earthquake occurrence probability of *Ms*≥7.0 in the next 100 years is 80.6±0.20% for their subregion 9 (around Bodrum-İstanköy) and 77.8±0.17% for their subregion 1 (including Balıkesir). Recurrence times for the earthquakes with the same magnitude have been found as 61 and 67 years in these subregions by Sayıl and Osmanşahin (2008). Their regions 1 and 9 cover Bakırçay graben (regions 17 and 18) and Muğla-Rhodes region (region 5) in this study. Although no anomaly is observed in Muğla and Rhodes region, the results in the regions including Bakırçay graben are similar with those of Sayıl and Osmanşahin (2008).

Öztürk et al. (2008) estimated the earthquake hazard parameters for different regions in and around Turkey using Gumbel's first asymptotic distribution. They estimated the mean return periods, the most probable maximum magnitude and the probability of an earthquake occurrence for a given magnitude in a period of 10, 25, 50, and 100 years for 24 regions in and around Turkey. Their regions 13 (including Burdur fault zone), 15 (covering Gediz graben, Aliağa-Dumlupınar faults) and 17 (Kütahya-Simav and Zeytindağ-Bergama faults) are updated in this study in order to compare such tectonic zones in smaller scale and detail. The results from Öztürk et al. (2008) show that the mean return period for *Ms*≥5.5 in their region 13 covering the Burdur fault zone (region 7 in this study) is equal to 24.55±0.28 years. For their region 15, including the Aliağa and Dumlupınar faults (regions 10 and 11 in this study), the value of the mean return period for Ms≥6.0 is calculated as 23.44±0.06 years. In their region 17 covering Kütahya, Simav, Soma and Bakırçay grabens and Zeytindağ-Bergama faults (regions 13, 14, 15, 16, 17 and 18 in this study), the mean return period value for the earthquakes with *Ms*≥6.0 is computed as 18.62±1.29 years. According the results from Öztürk et al. (2008), these short mean return periods for the earthquakes between 5.5 and 6.0 in mentioned regions, especially the Burdur fault zone, Bakırçay graben and Aliağa-Dumlıpınar faults, are important and in high risk. Thus, the next earthquake of such magnitude in these regions can be expected between 2017 and 2022.

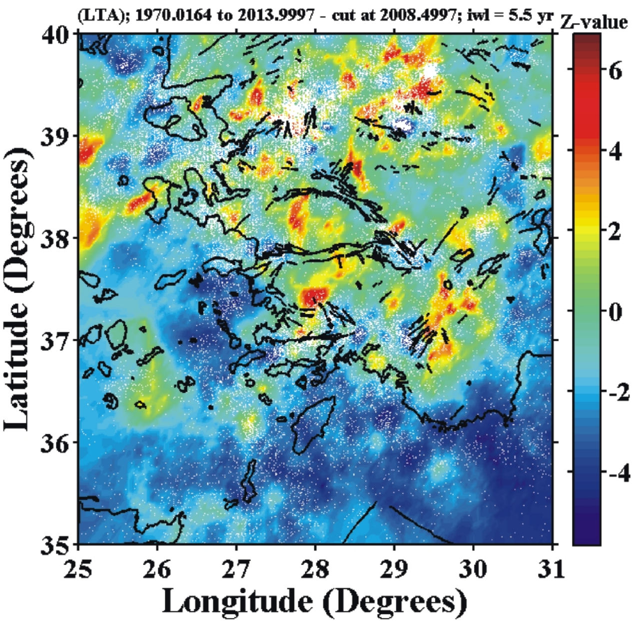

Figure 10: Spatial distribution of seismic quiescence *Z*-value in the beginning of 2014 with T_w (*iwl*) equal to 5.5 years for the Western Anatolian region. White dots show the declustered earthquakes with M_D≥2.8

Thus, spatial and temporal analysis of the current seismic behaviors of earthquakes may be the key to the future earthquake potential in the Western Anatolian region. For this reason, size scaling parameters such as *Dc*-value, *b*-value, *Z*-value and their relations must be more carefully estimated in order to reveal the significant anomalies prior to a strong earthquake in the next future. There is a current quiescence in the beginning of 2014 and the other seismotectonic parameters correlate with this quiescence. Consequently, special attention must be given to these anomaly regions in Western Anatolia.

6. Conclusions

This study focused on the spatial and temporal behaviors of the seismic activity in the Western Anatolian region of Turkey. In this scope, statistical correlation between seismotectonic *b*-value and *Dc*-value is estimated and the current seismicity rate changes in the beginning of 2014 are mapped. Earthquake catalogue, taken from KOERI, is homogeneous for duration magnitude, M_D and consists of 79,881 events with magnitudes between 1.0 and 6.7 from January 1, 1970 to January 1, 2014. Average *Mc*-value for whole study region from 1970 to 2014 is estimated as 2.8. Reasenberg's algorithm is used to decluster the catalog and then seismic quiescence *Z*-value is calculated. The Western Anatolian region was divided into 18 different seismogenic subregions to make a comprehensive study. The maximum likelihood method is used to calculate the *b*-values and linear regression with 95% confidence limit is used to obtain *Dc*-values.

Significant changes in seismic activity started after 2000 and there was an increase in the number of earthquakes with magnitudes greater than 5.5. However, great seismic changes started after 2005. Thus, seismic activity is more clustered at larger scales (or in smaller areas) in the West Anatolian region. According to the results of regional and temporal changes in seismotectonic parameters *b* and *Dc*-values, there are clear fluctuations in the study area. So, there has been a strong earthquake potential in the Western Anatolia because of these recent seismic fluctuations. The Burdur fault zone and Kütahya graben in which *b*-values are smaller than 1.0 must be given a special caution, as higher *Dc*-values are associated with lower *b*-values. To estimate a more up-to-date and reliable statistical relation between two seismotectonic parameters *b* and *Dc*-values, orthogonal regression is preferred. The relationship of $Dc=2.74-0.29*b$ is suggested with a strong enough negative correlation ($r = -0.73$) for the Western Anatolia earthquake distributions.

Regional variation of the seismicity rate changes is analyzed by generating LTA(*t*) function at the nodes of 0.05°x0.05° grid spaces. Using a moving time window T_w=5.5 years, seismic quiescence *Z*-value distribution in the beginning of 2014 is mapped. The regions exhibiting lower *b*-values and higher *Z*-values are observed in the Burdur fault zone, Aliağa-Dumlupınar faults and Bakırçay grabens. As a general result, the relationships between seismic *b*-value, fractal dimension *Dc*-value and seismic quiescence *Z*-value may provide significant clues to reveal the probable locations of future earthquakes in the Western Anatolian region.

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