An Analysis of Strain Accumulation in the Western Part of Black Sea Region in Turkey

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Key words: Deformation measurement, Engineering survey, Strain accumulation, Strain rate, Finite element model

SUMMARY

In this study, a test area limited 39.5°–42.0° northern latitudes and 31.0°–37.0° eastern longitudes was chosen. The benchmarks in this test area are composed of 30 geodetic control points derived with the aim of cadastral and engineering applications. These benchmarks are common points of European Datum 1950 (ED50) and Turkish National Fundamental GPS Network (TNFGN). It has been investigated the strain accumulation of 51 years in this region. The finite element analysis is used in order to derive the strain accumulation and rates in the test area. The results have been indicated that the minimum and maximum strains are 17µs and 3041µs, respectively.

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1. INTRODUCTION

Turkish National Horizontal Control Network (TNHCN) based on the European Datum 1950 (ED50) was used as the principal geodetic network until 2005 in Turkey. Since 2005, Turkish Large Scale Map and Map Information Production Regulation have required that that all the densification points have been produced within the same datum of Turkish National Fundamental GPS Network (TNFGN) put into practise in 2002 and based on International Terrestrial Reference Frame (ITRF). Hence, the common points were produced in both European Datum 1950 (ED50), and TNFGN.

It is known that the geological and geophysical information about the network area can be obtained by the evaluation of the coordinate and scale variations in a geodetic network. For one such evaluation, the coordinate variations and velocities of network points, and also the strains are investigated. However, the principal problem in derivation of velocities arises from two different datum. In this context, the computation of velocities using the coordinate data of the ED50 and TNFGN is not accurate and reliable. Likewise, the analysis of strain from the coordinate differences is not reliable. However, due to the fact that the ratio of baselines in a geodetic network is independent from datum, the strains can be derived from scale variations accurately and reliably.

2. TURKISH GEODETIC REFERENCE NETWORKS

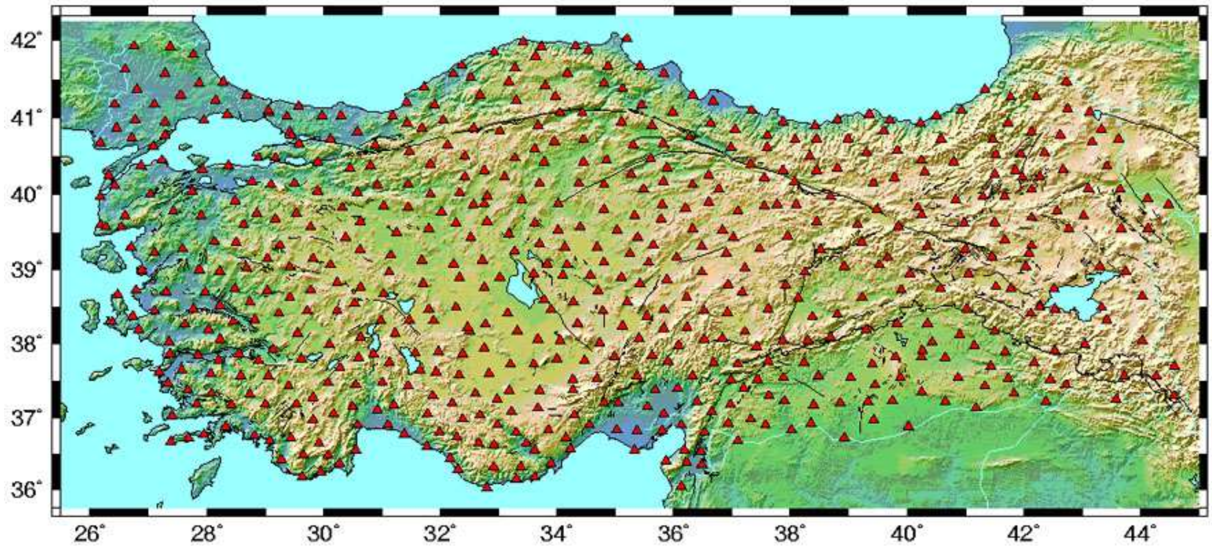
Turkish National Horizontal Control Network (TNHCN) was completed in early 1950s and was adjusted in 1954 (GCM, 2002). It was tied to ED50 with 8 European common stations.

Between 1997-1999, Turkish National Fundamental GPS Network (TNFGN) is formed in International Terrestrial Reference Frame 1996 (ITRF96) datum. Technical information about TNHCN and TNFGN is given the Table 1 below (Ayan et al, 2003). Both TNHCN and TNFGN can be seen in Figure 1.

Table 1 Technical information about TNHCN and TNFGN

	TNHCN	**TNFGN**
Datum	ED50	ITRF96
Ellipsoid	Hayford	GRS80
Adjustment	1954	1999

(a)



(b)

Figure 1 (a) Turkish National Horizontal Control Network (TNHCN), (b) Turkish National Fundamental GPS Network (TNFGN)

Both TNHCN and TNFGN have hierarchical network structure. Also, TNFGN is a 4 dimensional network (Ayan et al. 2003).

In this study, 30 common points of TNHCN and TNFGN are taken as test network. ED50 refers to TNHCN in 1954 epoch. Likewise, TNFGN refers to 2005 epoch. The coordinates of two epochs are converted from UTM to Lambert Conformal Conic Projection. The parameters used in the conversion are given below in Table 2. Also the distribution of 30 common points in the test area can be seen in Figure 2.

Table 2 Parameter values for Turkish Lambert Conformal Conic projection

Parameter	**Value**
Projection Type	Lambert Conformal Conic
φ_0	38°
λ_0	34°
South Standard Parallel φ_S	40.67°
North Standard Parallel φ_N	43.67°
False Easting E_0	1000000 m
False Northing N_b	0 m

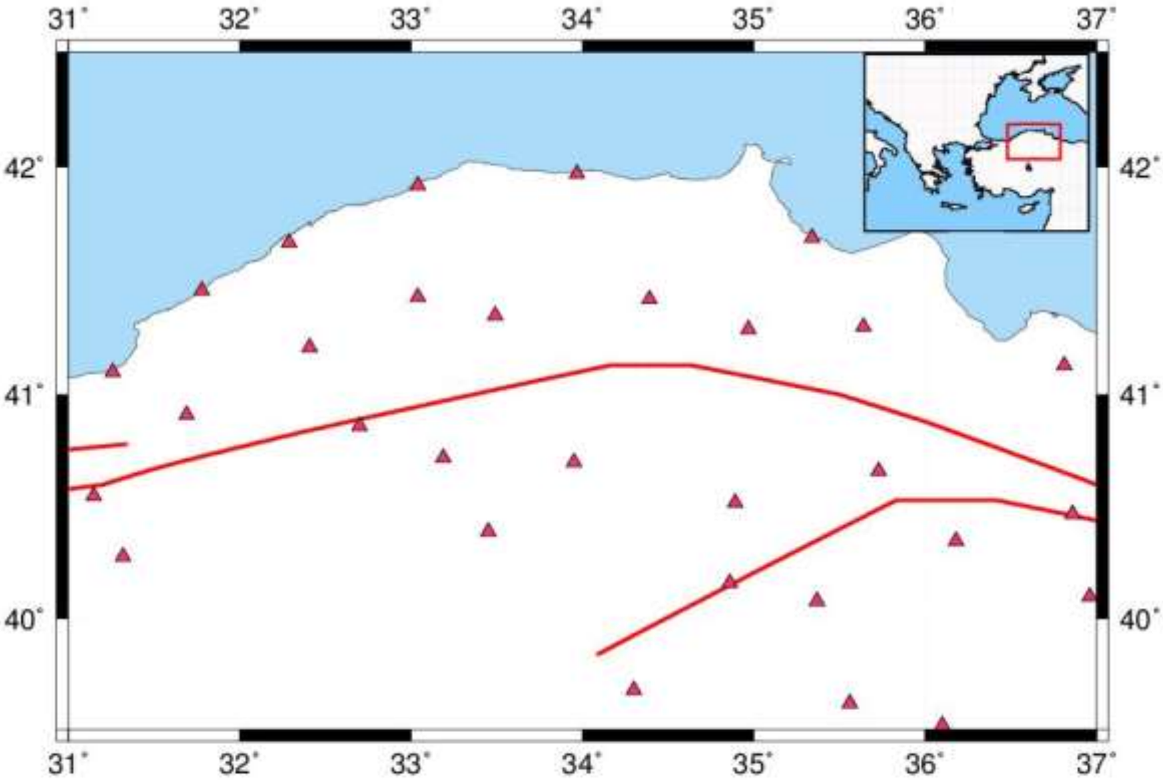


Figure 2 The distribution of 30 common points in the test area

3. INVESTIGATION OF STRAIN ACCUMULATION BY FINITE ELEMENT MODEL

Turkey is located in the collision zone between the African, Arabian and Eurasian plates, faces horizontal and vertical crustal movements. The North Anatolian Fault extends over 1500 km in the North of Turkey (Provost et al, 2003).

It should be also noted that since 1954, the earthquakes have not registered greater than magnitude 6.0 in the test area (Stein et al, 1997) (Figure 3). It is a considerable situation for this evaluation.

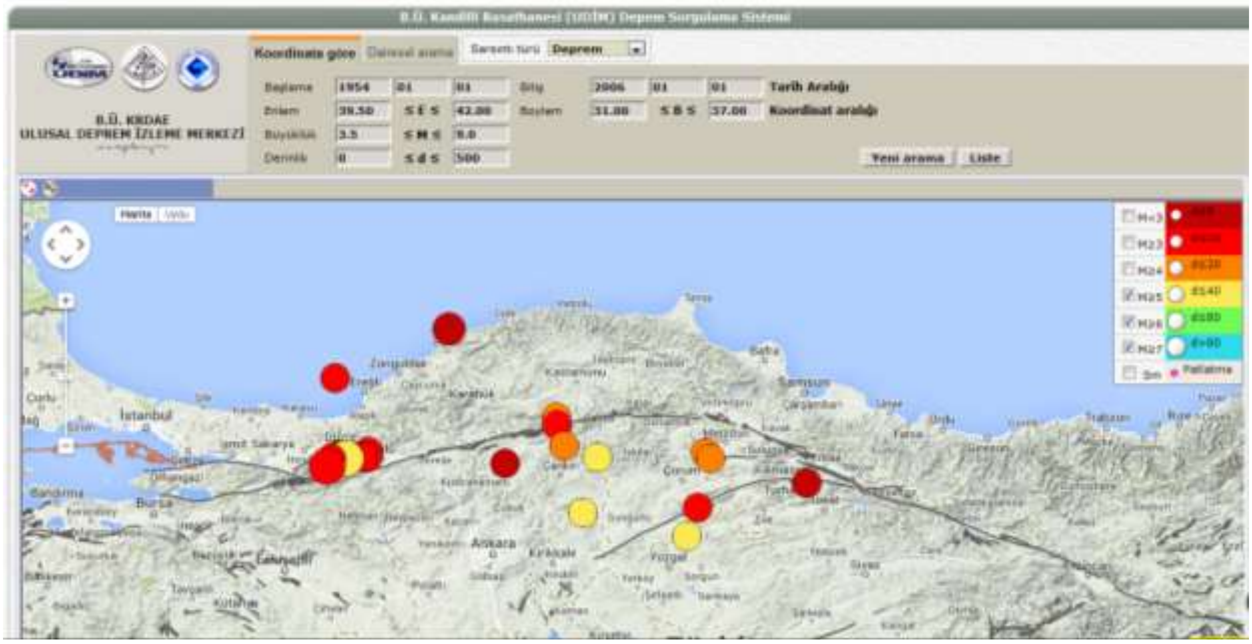


Figure 3 Earthquakes which are greater than magnitude 5.0 in the test area between 1954 and 2006 (URL-1)

In order to estimate a strain accumulation, the finite element model was employed. It is the most appropriate method to determine strain accumulation owing to the fact that it was independent from datum. It uses ratio of baselines. Least square adjustment is applied to observations at two epochs separately (Deniz and Ozener, 2010).

Linear extension of a baseline in a network becomes;

$$\varepsilon = \frac{S^{'} - S}{\Delta t . S} \qquad (1)$$

where S is the baseline length at first epoch, S’ is the baseline length at second epoch, Δt is the time interval between two epochs. If the time interval between two epochs is known, strain rate ε can be calculated. On the other hand, if it is not known, ε will become strain accumulation. Linear extension of the baseline ε is,

$$\varepsilon = e_{xx} \cos^2 t + e_{xy} \sin 2t + e_{yy} \sin^2 t \qquad (2)$$

where e_{xx}, e_{xy} and e_{yy} are the strain tensor parameters and t is the azimuth. The parameters of strain tensor are calculated by using Equation 2. To derive the strain parameters, three equations are required. Thus, the network is constructed of triangles by using Delaunay triangulation method. Then strain tensor for each triangle was calculated. (Denli, 1998).

Thus, for each triangle are found for time interval between two epochs. These parameters of strain tensor are the strain parameters of the point of equilibration of each triangle. Hereafter, strain parameters shown below could be calculated from the parameters of strain tensor.

$$\Delta = e_{xx} + e_{yy} \quad (3)$$

$$\gamma_1 = e_{xx} - e_{yy} \quad (4)$$

$$\gamma_2 = 2e_{xy} \quad (5)$$

$$\gamma = \sqrt{\gamma_1^2 + \gamma_2^2} \quad (6)$$

where Δ is dilatancy, γ_1 is principal shear strain, γ_2 is engineering shear strain and γ is total shear strain. Hereafter principal strain parameters are calculated by the following equations.

$$E_1 = \frac{1}{2}(\Delta + \gamma) \quad (7)$$

$$E_2 = \frac{1}{2}(\Delta - \gamma) \quad (8)$$

$$\beta = \arctan\left(\frac{e_{xy}}{E_1 - e_{xy}}\right) \quad (9)$$

where E_1 is maximum principal strain, E_2 is minimum principal strain and β is direction of maximum principal strain arc.

Principal strain parameters were calculated for the test area. Also, strain rate parameters were calculated by dividing principal strain parameters by 51 years (1954-2005). Strain rate parameters of the test area are given in Figure 4.

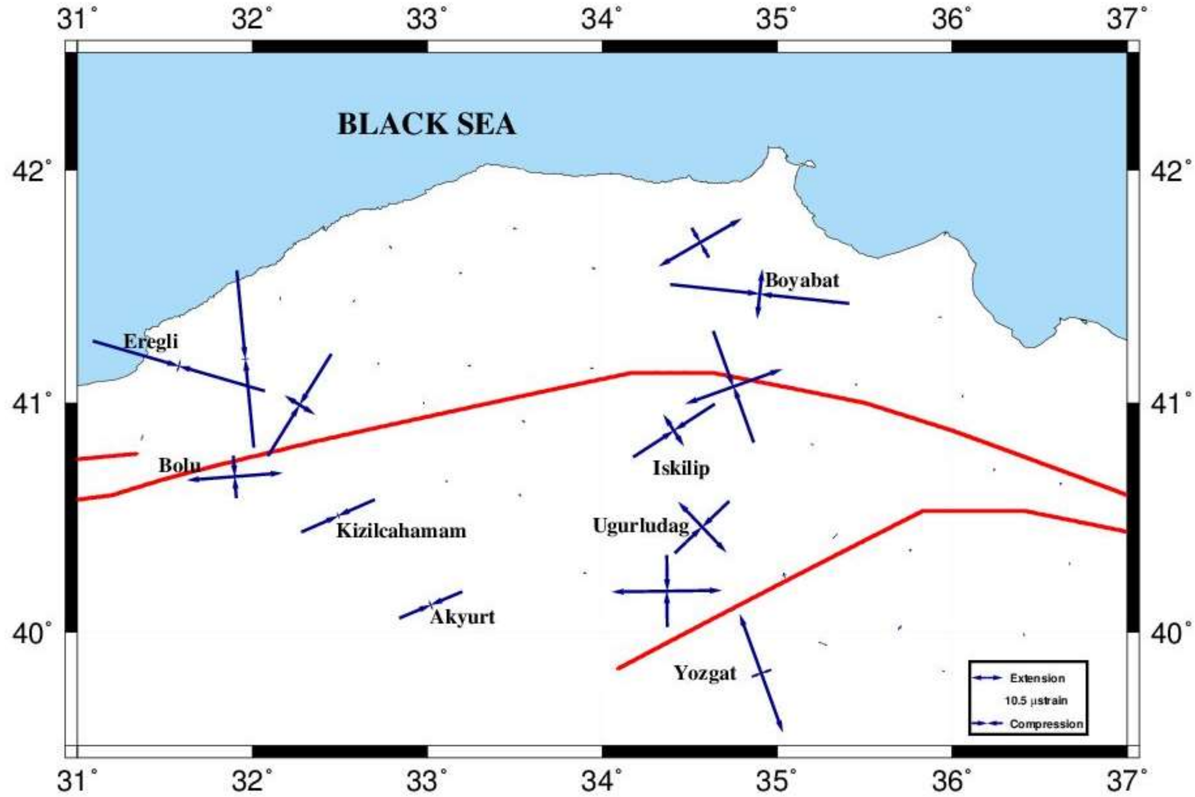


Figure 4 Principal strain rate parameters of the test area

Figure 4 shows that there is systematical distribution of strains in the test area. It also reveals that there are significant strain formations in the areas with values smaller than ±1μs average.

Figure 4 indicates that some areas have mean strain values of ±15-60μs; these areas approximately cover Eregli-Bolu-Kizilcahamam-Akyurt and Boyabat-Iskilip-Ugurludag-Yozgat. These results indicate that there are elastic and less elastic areas within the test area. Additionally, it is clear that the results should be examined in terms of geological and geophysical.

The precision of I., II., III. order of TNHCN and III. order Turkish National Densification Network, which is produced in accordance with Turkish Large Scale Map and Map Information Production Regulation – 1988 and tied to TNHCN, is about 1:5000 (±20ppm) at a 95% confidence level (CSCE, 1988).

The precision of C1 order in accordance with Turkish Large Scale Map and Map Information Production Regulation – 2005 is about ±5 ppm at a 95% confidence level which is equal to the precision of GPS measurements. According to the precision values mentioned above, the strain precision of the transformation between two networks (TNHCN and TNFGN) is ±21ppm.

The calculated strain values should be examined according to this limit. If the strain value is bigger than 21ppm, |strain|>21ppm, it will be considered as significant (CSCE, 2005).

Conclusions

Maximum values of strain rate were around Eregli-Bolu-Kizilcahamam-Akyurt and Boyabat-Iskilip-Ugurludag-Yozgat. Those areas have mean strain rate values of ±15-60µs. Also, the minimum values of strain accumulation were calculated around 17µs.

It is observed that there isn't a direct relationship between the derived strain rate and the faults. However, it should be considered that strain rate is dependent on the geological structure.

More detailed geodetic and geological research will be conducted in the study area.

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BIOGRAPHICAL NOTES

Ilke Deniz is a PhD student at department of Geomatics Engineering of The Institute of Natural and Applied Sciences at Bulent Ecevit University. She is a research assistant in the same department. She graduated from Yildiz Technical University in 2004 as Geodesy and Photogrammetry Engineer. She obtained M.Sc. degree from Geodesy Department of Bogazici University. Her PhD dissertation is about Determination of high accuracy precipitable water vapor using GNSS.

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Dr. Cetin Mekik was born in 1967. He graduated from Istanbul Technical University in 1988 as Geodesy and Photogrammetry Engineer. He obtained M.Phil. and Ph.D. degrees from Newcastle upon University, United Kingdom. He is currently working as an Associate Professor and researcher at Geomatics Engineering Department of Bulent Ecevit University in Turkey. He has specialized in GNSS, Network RTK (CORS networks) and GNSS Meteorology, and has recently been granted a COST Project called “Water Vapour Estimation using GPS” sponsored by the Scientific and Technological Research Council of Turkey.

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