Determination of Velocity Field and Strain Accumulation of Densification Network in Marmara Region

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Key words: Strain accumulation, Marmara Region, finite element model

SUMMARY

Global Positioning System (GPS) measurements have been used to obtain the information of the strain accumulation along fault lines. For the purpose of computing strain accumulation in Marmara Region, the densification network in Kirklareli, Tekirdag, Bursa, Bilecik, and Adapazari were measured by GPS technique by different institutions in 1999 and 2006. In this study, analysis of datum of 1999 observations and datum of 2006 observations were evaluated. The velocity field and strain accumulation by finite element model were calculated. The results for both conditions were given and evaluated in the study. Average of strain accumulations were calculated around Tekirdag and Izmit as 2.31µs and 3.40µs whereas average of strain accumulations was around Istanbul as 0.55 µs.

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1. INTRODUCTION

After the 1999 earthquakes, to eliminate effects of earthquake Turkish National Fundamental GPS Network (TNFGN) and Turkish National Vertical Control Network (TNVCN) were renovated. Thus, horizontal and vertical displacements which were formed during the earthquakes were determined and modeling the effects of earthquake was studied.

Densification of points tied to fundamental vertical and horizontal networks was also performed in this region. Istanbul GPS Triangulation Network (IGTN) and Marmara Earthquake Region Information System (MERLIS) including cities like Izmit, Adapazari and Yalova were formed.

Test network of Continuously Operating Reference Stations (CORS-TR) were established from some of the network points mentioned above as a national continuous GPS stations network in 2006 (CORS-TR, 2006). GPS measurements and adjustments of the test network were done by enterprises such as TOPCON, TRIMBLE, and LEICA.

The aims of this study are to evaluate the coordinate differences between the initial coordinates of the stations in test network (reduced to 2000.45 epochs) and average of adjusted coordinates which were calculated by three enterprises (reduced to 2006.60 epochs) and to determine strain accumulation in Marmara Region after the earthquakes.

2. TEST NETWORK AND OBSERVATIONS

Points of test networks were chosen from TNFGN, MERLIS and IGTN networks in Marmara Region. TNFGN, MERLIS and IGTN networks were tied to TNFGN which was tied to IGS network in ITRF96 datum. Test network was also tied to IGS network in ITRF2000 datum. Therefore, test networks had different datum for each epoch. The displacement vectors between 2000.45 epoch and 2006.60 epoch in test network were given in Figure 1.

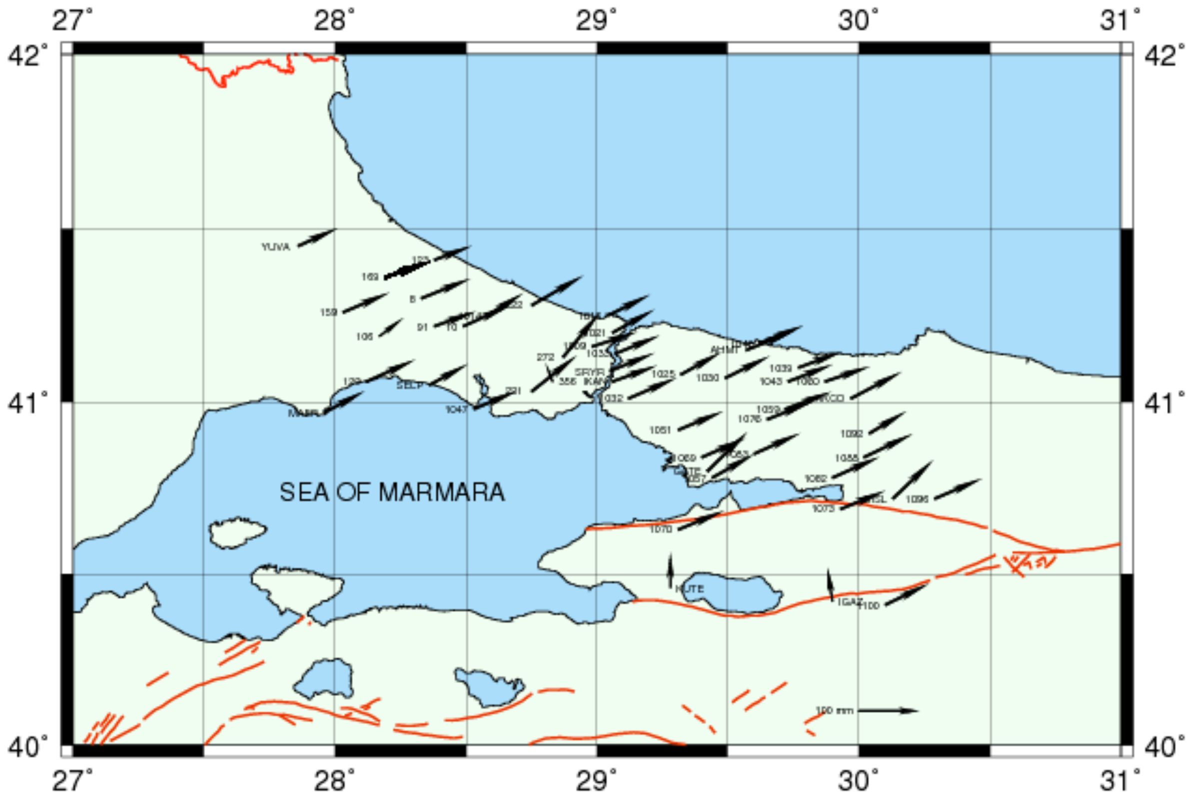

Figure 1. The displacement vectors between 2000.45 epoch and 2006.60 epoch in test network

3. DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

3.1 Determination of effects of datum

The coordinates of two epochs by using different IGS stations and different datum (ITRF96, ITRF2000) had an effect on coordinate differences was examined. TNFGN, MERLIS and IGTN networks were tied to TNFGN which was tied to IGS network using ONSA, MADR, WTZR, MATE, ANKR, ZWEN, KIT3, NICO and BAHR points. CORS-TR network was also tied to IGS network using ANKR, TUBI, DRAG, NOT1, SOFI, BUCU and MATE points. IGS stations of TNFGN were in ITRF96 datum, whereas IGS stations of CORS-TR were in ITRF2000 datum. By applying Helmert transformation between the coordinates of ITRF96 and ITRF2000 of IGS stations which made up datum of two networks, whether or not there were any significant scale changes and rotation were examined. Transformation parameters of each network were given in Table 1.

Table 1. Transformation Parameters of Each Network

	TNFGN	CORS-TR
Scale	1.000000001 ± 0.0000000006	1.000000190 ± 0.0000000270
Rotation about X	-0°00'00.00046" ± 0.00014"	-0°00'00.01077" ± 0.01260"
Rotation about Y	0°00'00.00027" ± 0.00021"	0°00'00.00089" ± 0.02874"
Rotation about Z	-0°00'00.00003" ± 0.00015"	-0°00'00.00371" ± 0.00597"
X translation	0.015 ± 0.006	-0.639 ± 0.613
Y translation	0.019 ± 0.004	-0.322 ± 0.255
Z translation	-0.022 ± 0.005	-1.008 ± 0.725

The table indicated that there was a significant translation between datum of two epochs. The translation had an effect on coordinate differences.

3.2 Determination of strain accumulation

The most appropriate way to determine strain parameters which were independent from datum is using ratio of baselines. Observations at two epochs are used for least square adjustment separately. Linear extension of a baseline in a network becomes;

$$\varepsilon = \frac{S^{'} - S}{\Delta t . S} \tag{4}$$

where S is original length,
$S^{'}$ is deformed length

If time interval between two epochs, Δt is given, strain rate ε is found. However; if Δt isn't taken into account, ε will become strain accumulation.

Linear extension of the baseline which has t azimuth is

$$\varepsilon = e_{xx} \cos^{2} t + e_{xy} \sin 2t + e_{yy} \sin^{2} t \tag{5}$$

By using this general equation, parameters of strain tensor are calculated. Therefore, the network has to be constructed of triangles and strain tensor has to be calculated for each triangle (Denli, 1998). For each baseline of a triangle, three general equations are created. Thus, e_{xx}, e_{xy}, e_{yy} are found for time interval between 2000.45 and 2006.60 epochs. These parameters of strain tensor are the strain parameters of the point of equilibration of each triangle (Deniz, 1997).

Triangles for the network were constructed by using Delaunay triangulation method. Then strain tensor for each triangle was calculated.

Subsequently, strain parameters shown below could be calculated from the parameters of strain tensor. (Deniz, 1997)

$$\Delta = e_{xx} + e_{yy} \quad \text{(Dilatancy)} \tag{9}$$

$$\gamma_1 = e_{xx} - e_{yy} \quad \text{(Principal shear strain)} \tag{10}$$

$$\gamma_2 = 2e_{xy} \quad \text{(Engineering shear strain)} \tag{11}$$

$$\gamma = \sqrt{\gamma_1^2 + \gamma_2^2} \quad \text{(Total shear strain)} \tag{12}$$

Principal strain parameters are calculated by the following equations.

$$E_1 = \frac{1}{2}(\Delta + \gamma) \quad \text{(Maximum principal strain)} \tag{13}$$

$$E_2 = \frac{1}{2}(\Delta - \gamma) \quad \text{(Minimum principal strain)} \tag{14}$$

$$\beta = \arctan\left(\frac{e_{xy}}{E_1 - e_{xy}}\right) \quad \text{(Direction of maximum principal strain arc)} \tag{15}$$

Principal strain parameters were calculated for test network. To make interpretations of the results easier, points of equilibration which have close strain parameters values were gathered into groups. Principal strain parameters of each group were given in Table 2 and Figure 2.

Table 2. Principal strain parameters of each group

Group Number	Coordinates of Point of Equilibration		Principal Strain Components		Angle of the principal Strain β (grad)
	Latitude(degree)	Longitude (degree)	E_1 (μs)	E_2 (μs)	
1	41,27	28,12	1,00	-1,15	7,08
2	41,21	28,34	2,31	0,03	-25,27
3	41,22	28,70	0,30	-1,09	-4,27
4	41,07	29,48	0,55	-1,00	39,76
5	40,87	29,79	0,77	-2,38	-17,92
6	40,62	29,84	3,40	-2,51	-10,82

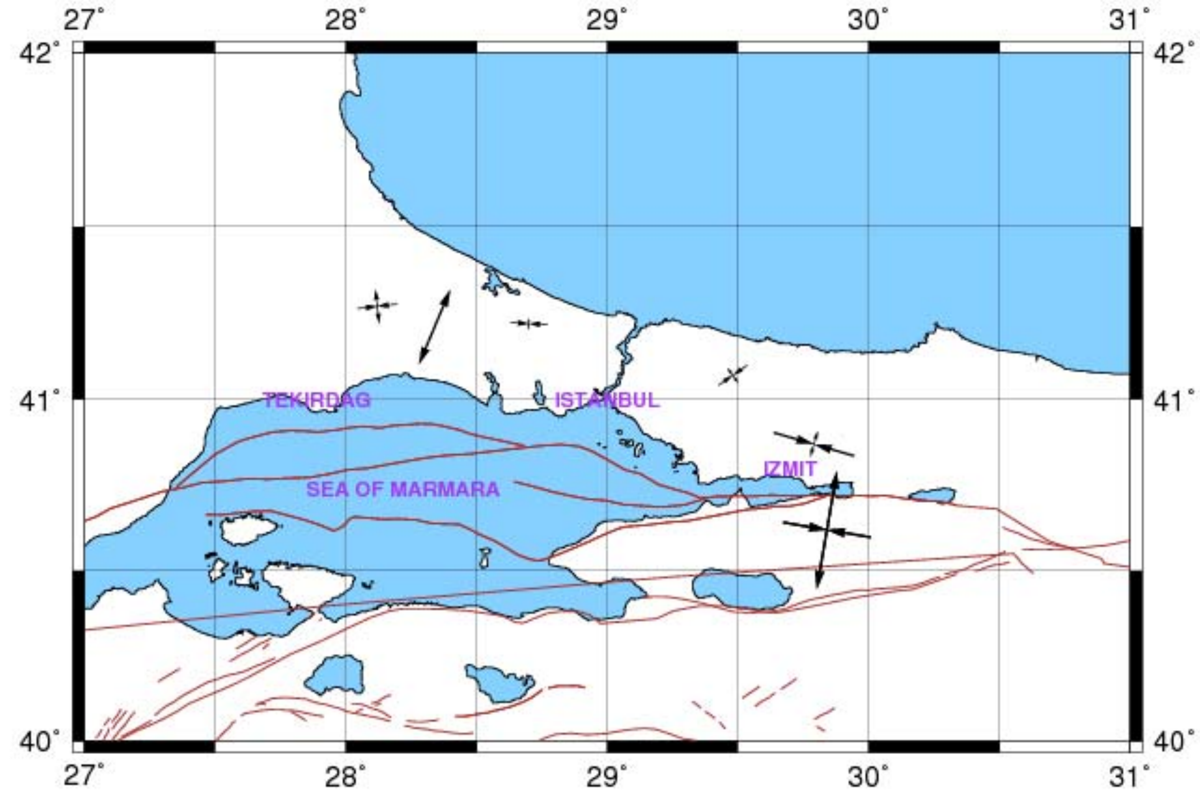

Figure 2. Principal strain parameters of each group

4. CONCLUSIONS

Coordinate differences indicated that there were significant displacement vectors between 2000.45 and 2006.60 epochs of test networks. Directions of these vectors were compatible with directions of displacement vectors derived from geodynamic studies.

In the computation of strain, choosing the model should be done according to the state of datum of networks. Strains should be calculated from data which were independent to datum. Most suitable model for this study was the determination of strain with finite element model that relied on the deformations of baselines of network.

Averages of strain accumulation were found around Tekirdag 2.31µs, around Izmit 3.40µs. Average of strain accumulation around the Istanbul was found 0.55µs.
The results were compatible with different geological structure of Tekirdag, Izmit and the Istanbul areas.

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